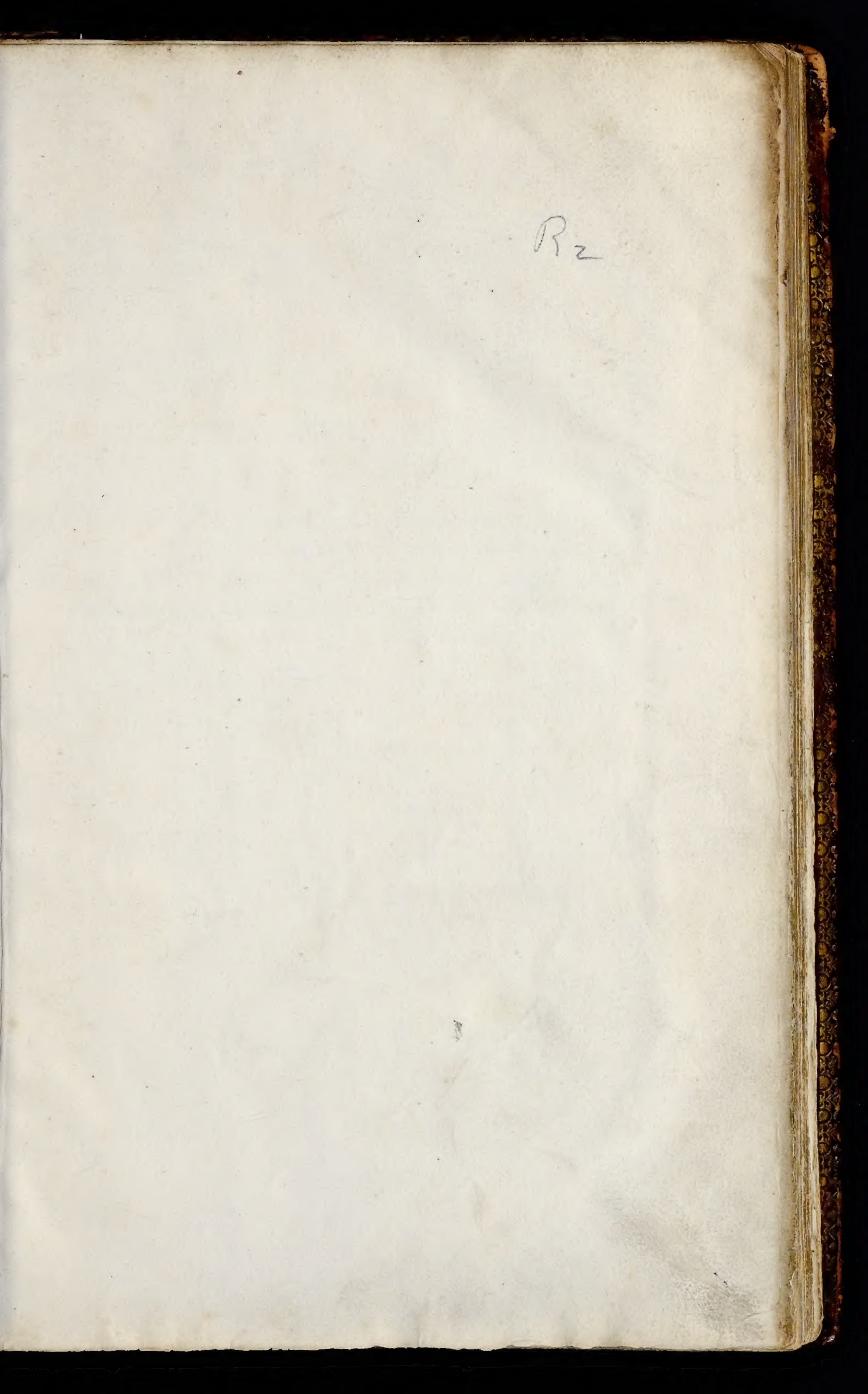
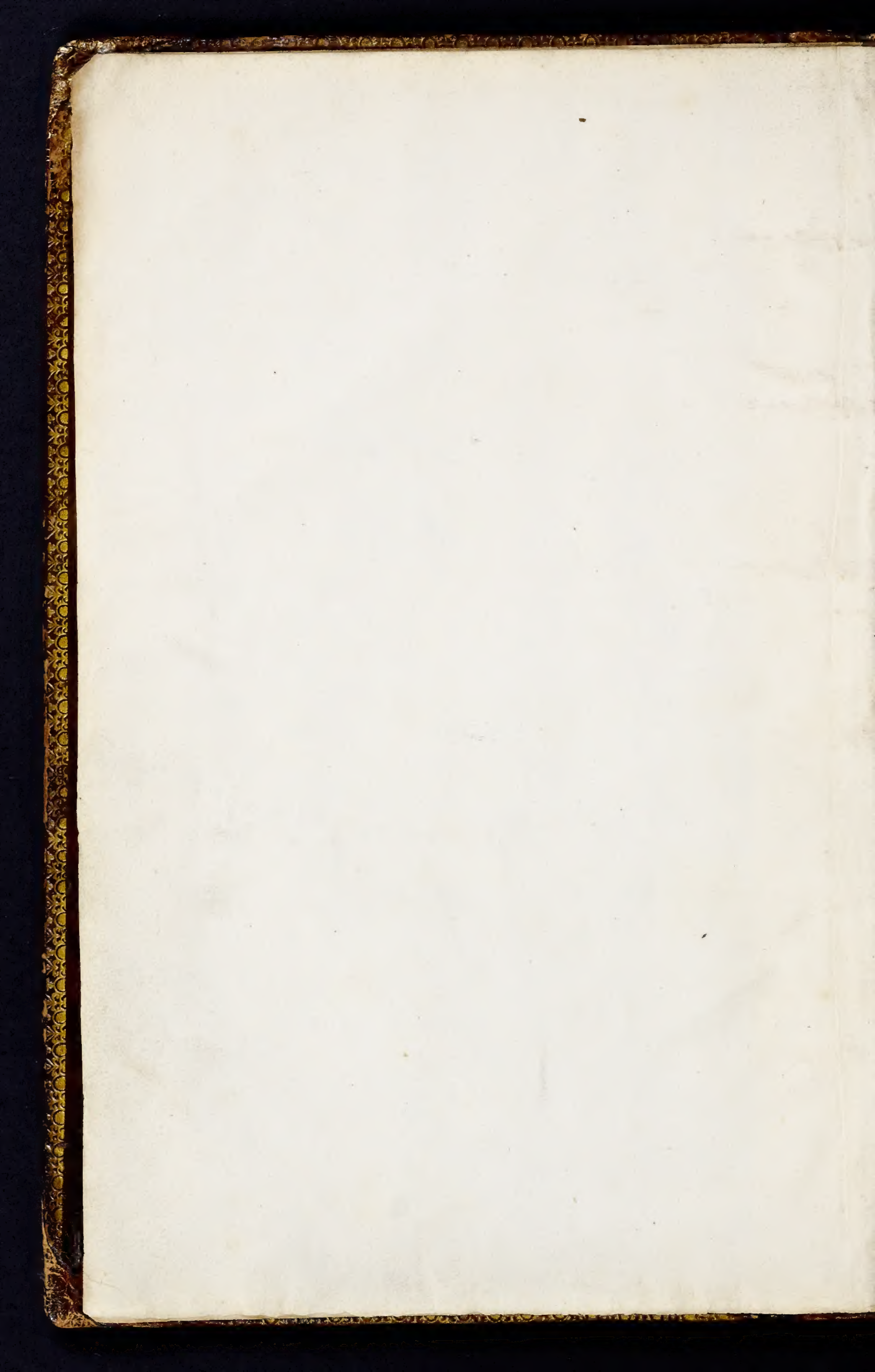
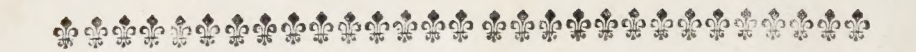










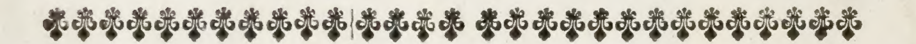


By the Council of the ROYAL SOCIETY of *London* for Improving of Natural Knowledge.

Ordered, *That the Book written by* Robert Hooke, *M.A. Fellow of this Society, Entituled*, Micrographia, or ſome Phyſiological Deſcriptions of Minute Bodies, made by Magnifying Glaſſes, with Obſervations and Inquiries thereupon, *Be printed by* John Martyn, *and* James Alleſtry, *Printers to the ſaid Society.*

Novem. 23.
1664.

BROUNCKER. *P. R. S.*



MICROGRAPHIA:

OR SOME

Physiological Descriptions

OF

MINUTE BODIES

MADE BY

MAGNIFYING GLASSES.

WITH

OBSERVATIONS and INQUIRIES thereupon.

By *R. HOOKE*, Fellow of the ROYAL SOCIETY.

Non possis oculo quantum contendere Linceus,
Non tamen idcirco contemnas Lippus inungi. Horat. Ep. lib. 1.



LONDON, Printed by *Jo. Martyn*, and *Ja. Allestry*, Printers to the ROYAL SOCIETY, and are to be sold at their Shop at the *Bell* in S. *Paul's* Church-yard. M DC LX V.



TO THE
KING.

SIR,

I Do here most humbly lay this *small* Present at *Your Majesties* Royal feet. And though it comes accompany'd with two *disadvantages*, the *meanness* of the *Author*, and of the *Subject*; yet in both I am *incouraged* by the *greatness* of your *Mercy* and your *Knowledge*. By the *one* I am taught, that you can

forgive the moſt *preſumptuous Offendors*: And by the *other*, that you will not *eſteem* the leaſt work of *Nature*, or *Art*, unworthy your *Obſervation*. Amidſt the many *felicities* that have accompani'd *your Majeſties* happy *Reſtauration* and *Government*, it is none of the leaſt conſiderable, that *Philoſophy* and *Experimental Learning* have *proſper'd* under your *Royal Patronage*. And as the calm proſperity of your Reign has given us the *leiſure* to follow theſe *Studies* of *quiet* and *retirement*, ſo it is juſt, that the *Fruits* of them ſhould, by way of *acknowledgement*, be return'd to *your Majeſty*. There are, Sir, ſeveral other of your Subjects, of your *Royal Society*, now buſie about *Nobler* matters: The *Improvement* of *Manufactures* and *Agriculture*, the *Increaſe* of *Commerce*, the *Advantage* of *Navigation*: In all which they are *aſsiſted* by *your Majeſties Incouragement* and *Example*. Amidſt all thoſe

greater

greater Deſigns, I here preſume to bring in that which is more *proportionable* to the *ſmalneſs* of my Abilities, and to offer ſome of the *leaſt* of all *viſible things*, to that *Mighty King*, that has *eſtabliſht an Empire* over the beſt of all *Inviſible things* of this World, the *Minds* of Men.

Your Majeſties moſt humble

and moſt obedient

Subject and Servant,

ROBERT HOOKE.



TO THE

ROYAL SOCIETY.



Fter my *Addreſs* to our *Great Founder* and *Patron*, I could not but think my ſelf oblig'd, in conſideration of thoſe *many Ingagements* you have laid upon me, to offer theſe my *poor Labours* to this MOST ILLUSTRIOUS ASSEMBLY. YOU have been pleas'd formerly to accept of theſe rude *Draughts*. I have ſince added to them ſome *Deſcriptions*, and ſome *Conjectures* of my own. And therefore, together with YOUR *Acceptance*, I muſt alſo beg YOUR *pardon*. The Rules YOU have preſcrib'd YOUR ſelves in YOUR Philoſophical Progreſs do ſeem the beſt that have ever yet been practis'd. And particularly that of avoiding *Dogmatizing*, and the *eſpouſal* of any *Hypotheſis* not ſufficiently grounded and confirm'd by *Experiments*. This way ſeems the moſt excellent, and may preſerve both *Philoſophy* and *Natural Hiſtory* from its former *Corruptions*. In ſaying which, I may ſeem to condemn my own Courſe in this Treatiſe; in which there may perhaps be ſome *Expreſſions*, which may ſeem more *poſitive* then YOUR Preſcriptions will permit: And though I deſire to have them underſtood only as *Conjectures* and *Quæries* (which YOUR Method does not altogether diſallow) yet if even in thoſe I have exceeded, 'tis fit that I ſhould declare, that it was not done by YOUR Directions. For it is moſt unreaſonable, that YOU ſhould undergo the *imputation* of the *faults* of my *Conjectures*, ſeeing YOU can receive ſo *ſmall advantage* of reputation by the *ſleight Obſervations* of

YOUR moſt humble and
moſt faithful Servant

ROBERT HOOKE.



THE PREFACE.

IT *is the great prerogative of Mankind above other Creatures, that we are not only able to* behold *the works of Nature, or barely to* ſuſtein *our lives by them, but we have alſo the power of* conſidering, comparing, altering, aſſiſting, *and* improving *them to various uſes. And as this is the peculiar priviledge of humane Nature in general, ſo is it capable of being ſo far advanced by the helps of Art, and Experience, as to make ſome Men excel others in their Obſervations, and Deductions, almoſt as much as they do Beaſts. By the addition of ſuch* artificial Inſtruments *and* methods, *there may be, in ſome manner, a reparation made for the miſchiefs, and imperfection, mankind has drawn upon it ſelf, by negligence, and intemperance, and a wilful and ſuperſtitious deſerting the Preſcripts and Rules of Nature, whereby every man, both from a deriv'd corruption, innate and born with him, and from his breeding and converſe with men, is very ſubject to ſlip into all ſorts of errors.*

The only way which now remains for us to recover ſome degree of thoſe former perfections, ſeems to be, by rectifying the operations of the Senſe, *the* Memory, *and* Reaſon, *ſince upon the evidence, the* ſtrength, *the* integrity, *and the* right correſpondence *of all theſe, all the light, by which our actions are to be guided, is to be renewed, and all our command over things is to be eſtabliſht.*

It is therefore moſt worthy of our conſideration, to recollect their ſeſeveral defects, that ſo we may the better underſtand how to ſupply them, and by what aſſiſtances we may inlarge *their power, and* ſecure *them in performing their particular duties.*

As for the actions of our Senſes, *we cannot but obſerve them to be in*

many particulars much outdone by those of other Creatures, and when at best, to be far short of the perfection they seem capable of: And these infirmities of the Senses arise from a double cause, either from the disproportion of the Object to the Organ, *whereby an infinite number of things can never enter into them, or else from* error in the Perception, *that many things, which come within their reach, are not received in a right manner.*

The like frailties are to be found in the Memory; *we often let many things* slip away *from us, which deserve to be retain'd; and of those which we treasure up, a great part is either* frivolous *or* false; *and if good, and substantial, either in tract of time* obliterated, *or at best so* overwhelmed *and buried under more frothy notions, that when there is need of them, they are in vain sought for.*

The two main foundations being so deceivable, it is no wonder, that all the succeeding works which we build upon them, of arguing, concluding, defining, judging, and all the other degrees of Reason, are lyable to the same imperfection, being, at best, either vain, or uncertain: So that the errors of the understanding *are answerable to the two other, being defective both in the quantity and goodness of its knowledge; for the limits, to which our thoughts are confi nd, are small in respect of the vast extent of Nature it self; some parts of it are* too large *to be comprehended, and some* too little *to be perceived. And from thence it must follow, that not having a full sensation of the Object, we must be very lame and imperfect in our conceptions about it, and in all the propositions which we build upon it; hence we often take the* shadow *of things for the* substance, *small* appearances *for good* similitudes, similitudes *for* definitions; *and even many of those, which we think to be the most solid definitions, are rather expressions of our own misguided apprehensions then of the true nature of the things themselves.*

The effects of these imperfections are manifested in different ways, according to the temper and disposition of the several minds of men, some they incline to gross ignorance *and stupidity, and others to a* presumptuous imposing *on other mens Opinions, and a* confident dogmatizing *on matters, whereof there is no assurance to be given.*

Thus

Thus all the uncertainty, and mistakes of humane actions, proceed either from the narrowness and wandring of our Senses, *from the slipperiness or delusion of our* Memory, *from the confinement or rashness of our* Understanding, *so that 'tis no wonder, that our power over natural causes and effects is so slowly improv'd, seeing we are not only to contend with the obscurity and* difficulty of the things *whereon we work and think, but even the* forces of our own minds *conspire to betray us.*

These being the dangers in the process of humane Reason, the remedies of them all can only proceed from the real, *the* mechanical, *the* experimental *Philosophy, which has this advantage over the Philosophy of* discourse *and* disputation, *that whereas that chiefly aims at the subtilty of its Deductions and Conclusions, without much regard to the first ground-work, which ought to be well laid on the Sense and Memory; so this intends the right ordering of them all, and the making them serviceable to each other.*

The first thing to be undertaken in this weighty work, is a watchfulness over the failings *and an* inlargement of the dominion, *of the Senses.*

To which end it is requisite, first, That there should be a scrupulous *choice, and a* strict examination, *of the reality, constancy, and certainty of the Particulars that we admit: This is the first rise whereon truth is to begin, and here the most severe, and most impartial diligence, must be imployed; the storing up of all, without any regard to evidence or use, will only tend to darkness and confusion. We must not therefore esteem the riches of our Philosophical treasure by the number only, but chiefly by the* weight; *the most* vulgar *Instances are not to be neglected, but above all, the most* instructive *are to be entertain'd; the footsteps of Nature are to be trac'd, not only in her* ordinary course, *but when she seems to be put to her shifts, to make many* doublings *and* turnings, *and to use some kind of art in indeavouring to avoid our discovery.*

The next care to be taken, in respect of the Senses, is a supplying of their infirmities with Instruments, *and, as it were, the adding of* artificial Organs *to the* natural; *this in one of them has been of late years*

accompliſht with prodigious benefit to all ſorts of uſeful knowledge, by the invention of Optical Glaſſes. By the means of Teleſcopes, there is nothing ſo far diſtant but may be repreſented to our view; and by the help of Microſcopes, there is nothing ſo ſmall, as to eſcape our inquiry; hence there is a new viſible World diſcovered to the underſtanding. By this means the Heavens are open'd, and a vaſt number of new Stars, and new Motions, and new Productions appear in them, to which all the antient Aſtronomers were utterly Strangers. By this the Earth it ſelf, which lyes ſo neer us, under our feet, ſhews quite a new thing to us, and in every little particle of its matter, we now behold almoſt as great a variety of Creatures, as we were able before to reckon up in the whole Univerſe it ſelf.

It ſeems not improbable, but that by theſe helps the ſubtilty of the compoſition of Bodies, the ſtructure of their parts, the various texture of their matter, the inſtruments and manner of their inward motions, and all the other poſſible appearances of things, may come to be more fully diſcovered; all which the antient Peripateticks were content to comprehend in two general and (unleſs further explain'd) uſeleſs words of Matter and Form. From whence there may ariſe many admirable advantages, towards the increaſe of the Operative, and the Mechanick Knowledge, to which this Age ſeems ſo much inclined, becauſe we may perhaps be inabled to diſcern all the ſecret workings of Nature, almoſt in the ſame manner as we do thoſe that are the productions of Art, and are manag'd by Wheels, and Engines, and Springs, that were deviſed by humane Wit.

In this kind I here preſent to the World my imperfect Indeavours; which though they ſhall prove no other way conſiderable, yet, I hope, they may be in ſome meaſure uſeful to the main Deſign of a reformation in Philoſophy, if it be only by ſhewing, that there is not ſo much requir'd towards it, any ſtrength of Imagination, or exactneſs of Method, or depth of Contemplation (though the addition of theſe, where they can be had, muſt needs produce a much more perfect compoſure) as a ſincere Hand, and a faithful Eye, to examine, and to record, the things themſelves as they appear.

And

And I beg my Reader, to let me take the boldneſs to aſſure him, that in this preſent condition of knowledge, a man ſo qualified, as I have indeavoured to be, only with reſolution, and integrity, and plain intentions of imploying his Senſes *aright, may venture to compare the reality and the uſefulneſs of his ſervices, towards the true Philoſophy, with thoſe of other men, that are of much ſtronger, and more acute* ſpeculations, *that ſhall not make uſe of the ſame method by the Senſes.*

The truth is, the Science of Nature has been already too long made only a work of the Brain *and the* Fancy*: It is now high time that it ſhould return to the plainneſs and ſoundneſs of* Obſervations *on* material *and* obvious *things. It is ſaid of great Empires, That* the beſt way to preſerve them from decay, is to bring them back to the firſt Principles, and Arts, on which they did begin. *The ſame is undoubtedly true in Philoſophy, that by wandring far away into* inviſible Notions, *has almoſt quite deſtroy'd it ſelf, and it can never be recovered, or continued, but by returning into the ſame* ſenſible paths, *in which it did at firſt proceed.*

If therefore the Reader expects from me any infallible Deductions, or certainty of Axioms, *I am to ſay for my ſelf, that thoſe ſtronger Works of Wit and Imagination are above my weak Abilities; or if they had not been ſo, I would not have made uſe of them in this preſent Subject before me: Whereever he finds that I have ventur'd at any ſmall Conjectures, at the cauſes of the things that I have obſerved, I beſeech him to look upon them only as* doubtful Problems, *and* uncertain gheſſes, *and not as unqueſtionable Concluſions, or matters of unconfutable Science; I have produced nothing here, with intent to bind his underſtanding to an* implicit *conſent; I am ſo far from that, that I deſire him, not abſolutely to rely upon theſe Obſervations of my eyes, if he finds them contradicted by the future Ocular Experiments of ſober and impartial Diſcoverers.*

As for my part, I have obtained my end, if theſe my ſmall Labours ſhall be thought fit to take up ſome place in the large ſtock of natural Obſervations, *which ſo many hands are buſie in providing. If I have contributed the* meaneſt foundations *whereon others may raiſe nobler*

Superstructures, *I am abundantly satisfied ; and all my ambition is, that I may serve to the great Philosophers of this Age , as the makers and the grinders of my* Glasses *did to me ; that I may prepare and furnish them with some* Materials, *which they may afterwards* order *and* manage *with better skill, and to far greater advantage.*

The next remedies in this universal cure of the Mind are to be applyed to the Memory, *and they are to consist of such Directions as may inform us, what things are best to be* stor'd up *for our purpose, and which is the best way of so* disposing *them, that they may not only be* kept in safety, *but ready and convenient, to be at any time* produc'd *for use, as occasion shall require. But I will not here prevent my self in what I may say in another Discourse , wherein I shall make an attempt to propose some Considerations of the manner of compiling a Natural and Artificial History, and of so ranging and registring its Particulars into Philosophical Tables, as may make them most useful for the raising of* Axioms *and* Theories.

The last indeed is the most hazardous *Enterprize, and yet the most* necessary ; *and that is, to take such care that the* Judgment *and the* Reason *of Man (which is the third Faculty to be repair'd and improv'd) should receive such assistance, as to avoid the dangers to which it is by nature most subject. The Imperfections, which I have already mention'd, to which it is lyable, do either belong to the* extent, *or the* goodness *of its knowledge ; and here the difficulty is the greater, least that which may be thought a* remedy *for the one should prove* destructive *to the other, least by seeking to inlarge our Knowledge, we should render it weak and uncertain ; and least by being too scrupulous and exact about every Circumstance of it, we should confine and streighten it too much.*

In both these the middle wayes are to be taken, nothing is to be omitted, *and yet every thing to pass a* mature deliberation *: No* Intelligence *from Men of all Professions, and quarters of the World, to be* slighted, *and yet all to be so* severely examin'd, *that there remain no room for doubt or instability ; much* rigour *in admitting, much* strictness *in comparing, and above all, much* slowness *in debating, and*

shyness

ſhyneſs *in determining, is to be practiſed. The* Underſtanding *is to* order *all the inferiour ſervices of the lower Faculties; but yet it is to do this only as a* lawful Maſter, *and not as a* Tyrant. *It muſt not* incroach *upon their Offices, nor take upon it ſelf the employments which belong to either of them. It muſt* watch *the irregularities of the Senſes, but it muſt not go before them, or* prevent *their information. It muſt* examine, range, *and* diſpoſe *of the bank which is laid up in the Memory; but it muſt be ſure to make* diſtinction *between the* ſober *and* well collected heap, *and the* extravagant Idea's, *and* miſtaken Images, *which there it may ſometimes light upon. So many are the* links, *upon which the true Philoſophy depends, of which, if any one be* looſe, *or* weak, *the whole* chain *is in danger of being diſſolv'd; it is to* begin *with the Hands and Eyes, and to* proceed *on through the Memory, to be* continued *by the Reaſon; nor is it to ſtop there, but to* come about *to the Hands and Eyes again, and ſo, by a* continual paſſage round *from one Faculty to another, it is to be maintained in life and ſtrength, as much as the body of man is by the* circulation *of the blood through the ſeveral parts of the body, the Arms, the Fat, the Lungs, the Heart, and the Head.*

If once this method were followed with diligence and attention, there is nothing that lyes within the power of human Wit (or which is far more effectual) of human Induſtry, which we might not compaſs; we might not only hope for Inventions to equalize thoſe of Copernicus, Galileo, Gilbert Harvy, *and of others, whoſe Names are almoſt loſt, that were the Inventors of* Gun-powder, *the* Seamans Compaſs, Printing, Etching, Graving, Microſcopes, &c. *but multitudes that may far exceed them: for even thoſe diſcoveries ſeem to have been the products of ſome ſuch method, though but imperfect; What may not be therefore expected from it if thoroughly proſecuted?* Talking *and* contention of Arguments *would ſoon be turn'd into* labours; *all the fine* dreams *of Opinions, and* univerſal metaphyſical natures, *which the luxury of ſubtil Brains has deviſ'd, would quickly vaniſh, and give place to* ſolid Hiſtories, Experiments *and* Works. *And as at firſt, mankind* fell *by* taſting *of the forbidden Tree of Knowledge, ſo we, their Poſterity, may be in part* reſtor'd

by

by the ſame way, not only by beholding *and* contemplating, *but by* taſting *too thoſe fruits of Natural knowledge, that were never yet forbidden.*

From hence the World may be aſſiſted with variety *of Inventions,* new *matter for Sciences may be* collected, *the* old improv'd, *and their* ruſt *rubb'd away; and as it is by the benefit of Senſes that we receive all our Skill in the works of Nature, ſo they alſo may be wonderfully benefited by it, and may be guided to an eaſier and more exact performance of their Offices; 'tis not unlikely, but that we may find out wherein our Senſes are deficient, and as eaſily find wayes of repairing them.*

The Indeavours of Skilful men have been moſt converſant about the aſſiſtance of the Eye, and many noble Productions have followed upon it; and from hence we may conclude, that there is a way open'd for advancing the operations, not only of all the other Senſes, but even of the Eye it ſelf; that which has been already done ought not to content us, but rather to incourage us to proceed further, and to attempt greater things in the ſame and different wayes.

'Tis not unlikely, but that there may be yet invented ſeveral other helps for the eye, as much exceeding thoſe already found, as thoſe do the bare eye, ſuch as by which we may perhaps be able to diſcover living Creatures *in the Moon, or other Planets, the* figures *of the compounding Particles of matter, and the particular* Schematiſms *and* Textures *of Bodies.*

And as Glaſſes *have highly promoted our* ſeeing, *ſo 'tis not improbable, but that there may be found many* Mechanical Inventions *to improve our other Senſes, of* hearing, ſmelling, taſting, touching. *'Tis not impoſſible to hear a* whiſper *a* furlongs *diſtance, it having been already done; and perhaps the nature of the thing would not make it more impoſſible, though that furlong ſhould be ten times multiply'd. And though ſome famous Authors have affirm'd it impoſſible to hear through the* thinneſt plate *of* Muſcovy-glaſs; *yet I know a way, by which 'tis eaſie enough to hear one ſpeak through a* wall a yard thick. *It has not been yet thoroughly examin'd, how far* Otocouſticons *may be improv'd, nor what other wayes there may be of* quickning *our hearing, or* conveying *ſound through* other bodies *then the* Air: *for that that is not the only* medium, *I can aſſure the Reader, that I have, by the help of a* diſtended wire, *propagated*

gated the ſound to a very conſiderable diſtance in an inſtant, or with as ſeemingly quick a motion as that of light, at leaſt, incomparably ſwifter then that, which at the ſame time was propagated through the Air; and this not only in a ſtraight line, or direct, but in one bended in many angles.

Nor are the other three ſo perfect, but that diligence, attention, and many mechanical contrivances, may alſo highly improve them. For ſince the ſenſe of ſmelling ſeems to be made by the ſwift paſſage of the Air (impregnated with the ſteams and effluvia of ſeveral odorous Bodies) through the griſly meanders of the Noſe whoſe ſurfaces are cover'd with a very ſenſible nerve, and moiſtned by a tranſudation from the proceſſus mamillares of the Brain, and ſome adjoyning glandules, and by the moiſt ſteam of the Lungs, with a Liquor convenient for the reception of thoſe effluvia and by the adheſion and mixing of thoſe ſteams with that liquor, and thereby affecting the nerve, or perhaps by inſinuating themſelves into the juices of the brain, after the ſame manner, as I have in the following Obſervations intimated, the parts of Salt to paſs through the skins of Effs, and Frogs. Since, I ſay, ſmelling ſeems to be made by ſome ſuch way, 'tis not improbable, but that ſome contrivance, for making a great quantity of Air paſs quick through the Noſe, might as much promote the ſenſe of ſmelling, as the any wayes hindring that paſſage does dull and deſtroy it. Several tryals I have made, both of hindring and promoting this ſenſe, and have ſucceeded in ſome according to expectation; and indeed to me it ſeems capable of being improv'd, for the judging of the conſtitutions of many Bodies. Perhaps we may thereby alſo judge (as other Creatures ſeem to do) what is wholſome, what poyſon; and in a word, what are the ſpecifick properties of Bodies.

There may be alſo ſome other mechanical wayes found out, of ſenſibly perceiving the effluvia of Bodies; ſeveral Inſtances of which, were it here proper, I could give of Mineral ſteams and exhalations; and it ſeems not impoſſible, but that by ſome ſuch wayes improved, may be diſcovered, what Minerals lye buried under the Earth, without the trouble to dig for them; ſome things to confirm this Conjecture may be found in Agricola, and other Writers of Minerals, ſpeaking of the Vegetables that are apt to thrive, or pine, in thoſe ſteams.

Whether also those steams, which seem to issue out of the Earth, and mix with the Air (and so to precipitate some aqueous *Exhalations, wherewith 'tis impregnated) may not be by some way detected before they produce the effect, seems hard to determine; yet something of this kind I am able to discover, by an Instrument I contriv'd to shew all the minute variations in the pressure of the Air; by which I constantly find, that before, and during the time of rainy weather, the pressure of the Air is less, and in* dry weather, *but especially when an* Eastern Wind *(which having past over vast tracts of Land is heavy with Earthy Particles) blows, it is much more, though these changes are varied according to very odd Laws.*

The Instrument is this. I prepare a pretty capaceous Bolt-head A B, with a small stem about two foot and a half long D C; upon the end of this D I put on a small bended Glass, or brazen *Syphon* D E F (open at D, E and F, but to be closed with cement at F and E, as occasion serves) whose stem F should be about six or eight inches long, but the bore of it not above half an inch diameter, and very even; these I fix very strongly together by the help of very hard Cement, and then fit the whole Glass A B C D E F into a long Board, or Frame, in such manner, that almost half the head A B may lye buried in a concave Hemisphere cut into the Board R S; then I place it so on the Board R S, as is exprest in the first Figure of the first Scheme; and fix it very firm and steady in that posture, so as that the weight of the *Mercury* that is afterwards to be put into it, may not in the least shake or stir it; then drawing a line X Y on the Frame R T, so that it may divide the ball into two equal parts, or that it may pass, as 'twere, through the center of the ball. I begin from that, and divide all the rest of the Board towards U T into inches, and the inches between the 25 and the end E (which need not be above two or three and thirty inches distant from the line X Y) I subdivide into Decimals; then stopping the end F with soft Cement, or soft Wax, I invert the Frame, placing the head downwards, and the Orifice E upwards; and by it, with a small Funnel, I fill the whole Glass with Quicksilver; then by stopping the small Orifice E with my finger, I oftentimes erect and invert the whole Glass and Frame, and thereby free the Quicksilver and Glass from all the bubbles or parcels of lurking Air; then inverting it as before, I fill it top full with clear and well strain'd Quicksilver, and having made ready a small ball of pretty hard Cement, by heat made very soft, I press it into the hole E, and thereby stop it very fast; and to secure this Cement from flying out afterward, I bind over it a piece of Leather, that is spread over in the inside with Cement, and wound about it whilst the Cement is hot: Having thus fastned it, I gently erect again the Glass after this manner: I first let the Frame down edge-wayes, till the edge R V touch the Floor, or ly horizontal; and then in that edging posture raise the end R S; this I do, that if there chance to be any Air hidden in the small Pipe E, it may ascend into the Pipe F, and not into the Pipe D C: Having thus erected it, and hung it by the hole Q, or fixt it perpendicularly by any other means, I open the end F,

and

and by a ſmall *Syphon* I draw out the *Mercury* ſo long,till I find the ſurface of it A B in the head to touch exactly the line X Y; at which time I immediately take away the *Syphon*, and if by chance it be run ſomewhat below the line X Y, by pouring in gently a little *Mercury* at F, I raiſe it again to its deſired height, by this contrivance I make all the ſenſible riſing and falling of the *Mercury* to be viſible in the ſurface of the *Mercury* in the Pipe F, and ſcarce any in the head A B. But becauſe there really is ſome ſmall change of the upper ſurface alſo, I find by ſeveral Obſervations how much it riſes in the Ball, and falls in the Pipe F, to make the diſtance between the two ſurfaces an inch greater then it was before; and the meaſure that it falls in the Pipe is the length of the inch by which I am to mark the parts of the Tube F, or the Board on which it lyes, into inches and Decimals: Having thus juſtned and divided it, I have a large Wheel M N O P, whoſe outmoſt limb is divided into two hundred equal parts; this by certain ſmall Pillars is fixt on the Frame R T, in the manner expreſt in the Figure. In the middle of this, on the back ſide, in a convenient frame, is placed a ſmall Cylinder, whoſe circumference is equal to twice the length of one of thoſe diviſions, which I find anſwer to an inch of aſcent, or deſcent, of *Mercury*: This Cylinder I, is movable on a very ſmall Needle, on the end of which is fixt a very light Index K L, all which are ſo pois'd on the Axis, or Needle, that no part is heavier then another: Then about this Cylinder is wound a ſmall Clew of Silk, with two ſmall ſteel Bullets at each end of it G H; one of theſe, which is ſomewhat the heavier, ought to be ſo big, as freely to move to and fro in the Pipe F; by means of which contrivance, every the leaſt variation of the height of the *Mercury* will be made exceeding viſible by the motion to and fro of the ſmall Index K L.

But this is but one way of diſcovering the effluvia *of the Earth mixt with the Air; there may be perhaps many others,witneſs the* Hygroſcope, *an Inſtrument whereby the watery ſteams volatile in the Air are diſcerned, which the Noſe it ſelf is not able to find. This I have deſcrib'd in the following Tract in the Deſcription of the Beard of a wild Oat. Others there are,may be diſcovered both by the Noſe, and by other wayes alſo. Thus the* ſmoak *of burning* Wood *is* ſmelt, ſeen, *and ſufficiently* felt *by the eyes: The* fumes *of burning* Brimſtone *are* ſmelt *and diſcovered alſo by the deſtroying the Colours of Bodies, as by the* whitening of a red Roſe: *And who knows, but that the Induſtry of man, following this method,may find out wayes of improving this ſenſe to as great a degree of perfection as it is in any Animal, and perhaps yet higher.*

'Tis not improbable alſo,but that our taſte *may be very much improv'd, either by* preparing *our taſt for the Body, as, after eating* bitter *things,* Wine,*or other* Vinous liquors, *are more ſenſibly taſted; or elſe by* preparing

paring *Bodies for our tast; as the dissolving of Metals with acid Liquors, make them tastable, which were before altogether insipid; thus* Lead *becomes* sweeter *then Sugar, and* Silver *more* bitter *then Gall,* Copper *and* Iron *of most* loathsome *tasts. And indeed the businesß of this sense being to discover the presence of dissolved Bodies in Liquors put on the Tongue, or in general to discover that a fluid body has some solid body dissolv'd in it, and what they are; whatever contrivance makes this discovery improves this sense. In this kind the mixtures of Chymical Liquors afford many Instances; as the sweet Vinegar that is impregnated with Lead may be discovered to be so by the affusion of a little of an* Alcalizate solution*: The bitter liquor of* Aqua fortis *and* Silver *may be discover'd to be charg'd with that Metal, by laying in it some plates of Copper: 'Tis not improbable also, but there may be multitudes of other wayes of discovering the parts dissolv'd, or dissoluble in liquors; and what is this discovery but a kind of* secundary tasting.

'Tis not improbable also, but that the sense of feeling *may be highly improv'd, for that being a sense that judges of the more* groß *and* robust motions *of the* Particles *of* Bodies, *seems capable of being improv'd and assisted very many wayes. Thus for the distinguishing of* Heat *and* Cold, *the* Weather-glaß *and* Thermometer, *which I have describ'd in this following Treatise, do exceedingly perfect it; by each of which the least variations of heat or cold, which the most Acute sense is not able to distinguish, are manifested This is oftentimes further promoted also by the help of* Burning-glasses, *and the like, which collect and unite the radiating heat. Thus the* roughneß *and* smoothneß *of a Body is made much more sensible by the help of a* Microscope, *then by the most* tender *and* delicate Hand. *Perhaps, a Physitian might, by several other* tangible *proprieties, discover the constitution of a Body as well as by the* Pulse. *I do but instance in these, to shew what possibility there may be of many others, and what probability and hopes there were of finding them, if this method were followed; for the Offices of the five Senses being to detect either the* subtil *and* curious Motions *propagated through all* pellucid *or perfectly* homogeneous *Bodies; Or the more* groß *and* vibrative Pulse *communicated through the* Air *and all other convenient* mediums, *whether fluid or solid: Or the* effluvia

effluvia *of Bodies* diſſolv'd *in the* Air ; *Or the* particles *of bodies* diſſolv'd *or* diſſoluble *in* Liquors, *or the more* quick *and* violent ſhaking motion *of* heat *in all or any of theſe: whatſoever does any wayes promote any of theſe kinds of* criteria, *does afford a way of improving ſome one ſenſe. And what a multitude of theſe would a diligent Man meet with in his inquiries? And this for the helping and promoting the* ſenſitive faculty *only.*

Next, as for the Memory, *or* retentive faculty, *we may be ſufficiently inſtructed from the* written Hiſtories *of* civil actions, *what great aſſiſtance may be afforded the Memory, in the committing to writing things obſervable in* natural operations. *If a Phyſitian be therefore accounted the more able in his Faculty, becauſe he has had long experience and practice, the remembrance of which, though perhaps very imperfect, does regulate all his after actions: What ought to be thought of that man, that has not only a perfect* regiſter *of his own experience, but is grown* old *with the experience of many hundreds of years, and many thouſands of men.*

And though of late, men, beginning to be ſenſible of this convenience, have here and there regiſtred and printed ſome few Centuries, *yet for the moſt part they are ſet down very lamely and imperfectly, and, I fear, many times not ſo truly, they ſeeming, ſeveral of them, to be deſign'd more for* Oſtentation *then* publique uſe: *For, not to inſtance, that they do, for the moſt part, omit thoſe Experiences they have made, wherein their Patients have miſcarried, it is very eaſie to be perceiv'd, that they do all along* hyperbolically extol *their own Preſcriptions, and vilifie thoſe of others. Notwithſtanding all which, theſe kinds of Hiſtories are generally eſteem'd uſeful, even to the ableſt Phyſitian.*

What may not be expected from the rational *or* deductive Faculty *that is furniſht with ſuch* Materials, *and thoſe ſo readily* adapted, *and rang'd for uſe, that in a moment, as 'twere, thouſands of Inſtances, ſerving for the* illuſtration, determination, *or* invention, *of almoſt any inquiry, may be* repreſented *even to the ſight? How neer the nature of* Axioms *muſt all thoſe* Propoſitions *be which are examin'd before ſo many* Witneſſes? *And how difficult will it be for any, though never ſo ſubtil an error in Philoſophy, to* ſcape *from being diſcover'd, after it has indur'd the* touch, *and ſo many other* tryals?

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What kind of mechanical way, and physical invention also is there requir'd, that might not this way be found out? The Invention *of a way to find the* Longitude *of places is easily perform'd, and that to as great* perfection *as is desir'd, or to as great an* accurateness *as the* Latitude *of places can be found at Sea; and perhaps yet also to a greater certainty then that has been hitherto found, as I shall very speedily freely manifest to the world. The way of* flying *in the Air seems principally unpracticable, by reason of the* want of strength *in* humane muscles; *if therefore that could be suppli'd, it were, I think, easie to make twenty contrivances to perform the office of* Wings: *What Attempts also I have made for the supplying that Defect, and my successes therein, which, I think, are wholly new, and not inconsiderable, I shall in another place relate.*

'Tis not unlikely also, but that Chymists, *if they followed this method, might find out their so much sought for* Alkahest. *What an* universal Menstruum, *which dissolves all sorts of* Sulphureous Bodies, *I have discover'd (which has not been before taken notice of as such) I have shewn in the sixteenth Observation.*

What a prodigious variety of Inventions in Anatomy *has this latter Age afforded, even in our own Bodies, in the very* Heart, *by which we live, and the* Brain, *which is the seat of our knowledge of other things? witness all the excellent Works of* Pecquet, Bartholinus, Billius, *and many others; and at home, of Doctor* Harvy, *Doctor* Ent, *Doctor* Willis, *Doctor* Glisson. *In* Celestial Observations *we have far exceeded all the Antients, even the* Chaldeans *and* Egyptians *themselves, whose* vast Plains, high Towers, *and* clear Air, *did not give them so great advantages over us, as we have over them by our* Glasses. *By the help of which, they have been very much outdone by the famous* Galileo, Hevelius, Zulichem; *and our own Countrymen, Mr.* Rook, *Doctor* Wren, *and the great Ornament of our Church and Nation, the* Lord Bishop of Exeter. *And to say no more in* Aerial Discoveries, *there has been a wonderful progress made by the* Noble Engine *of* the most Illustrious Mr. Boyle, *whom it becomes me to mention with all honour, not only as my particular Patron, but as the* Patron *of* Philosophy *it self; which he every day* increases *by his* Labours, *and* adorns *by his* Example.

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The good succeß of all these great Men,*and many others, and the now seemingly great* obviousness *of most of their and divers other Inventions, which from the beginning of the world have been, as 'twere, trod on, and yet not minded till these last* inquisitive *Ages (an Argument that there may be yet behind multitudes of the like) puts me in mind to recommend such Studies,and the prosecution of them by such methods, to the* Gentlemen *of our Nation,whose* leisure *makes them fit to* undertake, *and the* plenty *of their fortunes to* accomplish, *extraordinary things in this way. And I do not only propose this kind of* Experimental Philosophy *as a matter of high* rapture *and* delight *of the mind, but even as a* material *and* sensible Pleasure. *So vast is the* variety of Objects *which will come under their Inspections, so many* different wayes *there are of* handling *them, so great is the* satisfaction *of* finding *out* new things, *that I dare compare the* contentment *which they will injoy,not only to that of* contemplation, *but even to that which most men prefer of* the very Senses themselves.

And if they will please to take any incouragement from so mean and so imperfect endeavours as mine, upon my own experience, I can assure them,without arrogance, That there has not been any inquiry or Problem in Mechanicks, *that I have hitherto propounded to my self, but by a certain method (which I may on some other opportunity explain) I have been able presently to examine the possibility of it ; and if so, as easily to excogitate divers wayes of performing it : And indeed it is possible to do as much by* this method *in* Mechanicks, *as by* Algebra *can be perform'd in* Geometry. *Nor can I at all doubt, but that the same method is as applicable to* Physical Enquiries , *and as likely to find and reap thence as plentiful a crop of Inventions ; and indeed there seems to be no subject so barren,but may with this good husbandry be highly improv'd.*

Toward the prosecution of this method in Physical Inquiries, *I have here and there* gleaned *up an* handful *of Observations, in the collection of most of which I made use of* Microscopes, *and some other* Glasses *and* Instruments *that improve the sense ; which way I have herein taken , not that there are not multitudes of useful and pleasant Observables, yet uncollected,obvious enough without the helps of Art , but only to promote the use of Mechanical helps for the Senses,both in the surveying the already visible World,*

World, and for the discovery of many others hitherto unknown, and to make us, with the great Conqueror, to be affected that we have not yet overcome one World when there are so many others to be discovered, every considerable improvement of Telescopes *or* Microscopes *producing new Worlds and* Terra-Incognita's *to our view.*

The Glasses I used were of our English make, but though very good of the kind, yet far short of what might be expected, could we once find a way of making Glasses Elliptical, or of some more true shape; for though both Microscopes, *and* Telescopes, *as they now are, will magnifie an Object about a thousand thousand times bigger then it appears to the naked eye; yet the Apertures of the Object-glasses are so very small, that very few Rays are admitted, and even of those few there are so many false, that the Object appears* dark *and* indistinct: *And indeed these inconveniences are such, as seem inseparable from Spherical Glasses, even when most exactly made; but the way we have hitherto made use of for that purpose is so imperfect, that there may be perhaps ten wrought before one be made tolerably good, and most of those ten perhaps every one differing in goodness one from another, which is an Argument, that the way hitherto used is, at least, very uncertain. So that these Glasses have a double defect; the one, that very few of them are exactly true wrought; the other, that even of those that are best among them, none will admit a sufficient number of Rayes to magnifie the Object beyond a determinate bigness. Against which Inconveniences the only Remedies I have hitherto met with are these.*

First, for *Microscopes* (where the Object we view is near and within our power) the best way of making it appear bright in the Glass, is to cast a great quantity of light on it by means of *convex glasses*, for thereby, though the aperture be very small, yet there will throng in through it such multitudes, that an Object will by this means indure to be magnifi'd as much again as it would be without it. The way for doing which is this. I make choice of some Room that has only one window open to the South, and at about three or four foot distance from this Window, on a Table, I place my *Microscope*, and then so place either a round Globe of Water, or a very deep clear *plano convex* Glass (whose convex side is turn'd towards the Window) that there is a great quantity of Rayes collected and thrown upon the Object: Or if the Sun shine, I place a small piece of oyly Paper very near the Object, between that and the light; then with a good large Burning-Glass I so collect and throw the Rayes on the Paper, that there may be a very great quantity of light pass through it to the Object; yet I so proportion that light, that it may

may not ſinge or burn the Paper. Inſtead of which Paper there may be made uſe of a ſmall piece of Looking-glaſs plate, one of whoſe ſides is made rough by being rubb'd on a flat Tool with very fine ſand, this will, if the heat be leiſurely caſt on it, indure a much greater degree of heat, and conſequently very much augment a convenient light. By all which means the light of the Sun, or of a Window, may be ſo caſt on an Object, as to make it twice as light as it would otherwiſe be without it, and that without any inconvenience of glaring, which the immediate light of the Sun is very apt to create in moſt Objects; for by this means the light is ſo equally diffuſed, that all parts are alike inlightned; but when the immediate light of the Sun falls on it, the reflexions from ſome few parts are ſo vivid, that they drown the appearance of all the other, and are themſelves alſo, by reaſon of the inequality of light, indiſtinct, and appear only radiant ſpots.

But becauſe the light of the Sun, and alſo that of a Window, is in a continual variation, and ſo many Objects cannot be view'd long enough by them to be throughly examin'd; beſides that, oftentimes the Weather is ſo dark and cloudy, that for many dayes together nothing can be view'd: And becauſe alſo there are many Objects to be met with in the night, which cannot ſo conveniently be kept perhaps till the day, therefore to procure and caſt a ſufficient quantity of light on an Object in the night, I thought of, and often uſed this, Expedient.

I procur'd me a ſmall Pedeſtal, ſuch as is deſcrib'd in the fifth Figure of the firſt *Scheme* on the ſmall Pillar A B, of which were two movable Armes C D, which by means of the Screws E F, I could fix in any part of the Pillar; on the undermoſt of theſe I plac'd a pretty large Globe of Glaſs G, fill'd with exceeding clear Brine, ſtopt, inverted, and fixt in the manner viſible in the Figure; out of the ſide of which Arm proceeded another Arm H, with many joynts; to the end of which was faſtned a deep plain *Convex glaſs* I, which by means of this Arm could be moved to and fro, and fixt in any poſture. On the upper Arm was placed a ſmall Lamp K, which could be ſo mov'd upon the end of the Arm, as to be ſet in a fit poſture to give light through the Ball: By means of this Inſtrument duly plac'd, as is expreſt in the Figure, with the ſmall flame of a Lamp may be caſt as great and convenient a light on the Object as it will well indure; and being always conſtant, and to be had at any time. I found moſt proper for drawing the repreſentations of thoſe ſmall Objects I had occaſion to obſerve.

None of all which ways (though much beyond any other hitherto made uſe of by any I know) do afford a ſufficient help, but after a certain degree of magnifying, they leave us again in the lurch. Hence it were very deſirable, that ſome way were thought of for making the Object-glaſs of ſuch a Figure as would conveniently bear a large Aperture.

As for Teleſcopes, *the only improvement they ſeem capable of, is the increaſing of their length; for the Object being remote, there is no thought of giving it a greater light then it has; and therefore to augment the Aperture, the Glaſs muſt be ground of a very large ſphere; for, by that*

means,

means,the longer the Glaſs be, the bigger aperture will it bear,if the Glaſſes be of an equal goodneſs in their kind. Therefore a ſix will indure a much larger Aperture then a three foot Glaſs; and a ſixty foot Glaſs will proportionably bear a greater Aperture then a thirty,and will as much excel it alſo as a ſix foot does a three foot, as I have experimentally obſerv'd in one of that length made by Mr. Richard Reives *here at* London, *which will bear an Aperture above three inches over, and yet make the Object proportionably big and diſtinct; whereas there are very few thirty foot Glaſſes that will indure an Aperture of more then two inches over. So that for* Teleſcopes, *ſuppoſing we had a very ready way of making their Object Glaſſes of exactly ſpherical Surfaces, we might, by increaſing the length of the Glaſs, magnifie the Object to any aſſignable bigneſs. And for performing both theſe, I cannot imagine any way more eaſie,and more exact, then by this following Engine,by means of which, any Glaſſes,of what length ſoever,may be ſpeedily made.It ſeems the moſt eaſie, becauſe with one and the ſame Tool may be with care ground an Object Glaſs, of any length or breadth requiſite, and that with very little or no trouble in fitting the Engine, and without much skill in the Grinder. It ſeems to be the moſt exact, for to the very laſt ſtroke the Glaſs does regulate and rectifie the Tool to its exact Figure; and the longer or more the Tool and Glaſs are wrought together, the more exact will both of them be of the deſir'd Figure. Further, the motions of the Glaſs and Tool do ſo croſs each other, that there is not one point of eithers Surface,but has thouſands of croſs motions thwarting it, ſo that there can be no kind of Rings or Gutters made either in the Tool or Glaſs.*

The contrivance of the Engine is, only to make the ends of two large *Mandrils* ſo to move, that the Centers of them may be at any convenient diſtance aſunder, and that the *Axis* of the *Mandrils* lying both in the ſame plain produc'd, may meet each other in any aſſignable Angle; both which requiſites may be very well perform'd by the Engine deſcrib'd in the third Figure of the firſt *Scheme*: where A B ſignifies the Beam of a Lath fixt perpendicularly or Horizontally, C D the two Poppet heads, fixt at about two foot diſtance, E F an Iron *Mandril*,whoſe tapering neck F runs in an adapted tapering braſs Collar; the other end E runs on the point of a Screw G; in a convenient place of this is faſtned H a pully Wheel, and into the end of it,that comes through the Poppet head C, is ſcrewed a Ring of a hollow *Cylinder* K, or ſome other conveniently ſhap'd Tool, of what wideneſs ſhall

be

be thought moſt proper for the cize of Glaſſes, about which it is to be imploy'd: As, for Object glaſſes, between twelve foot and an hundred foot long, the Ring may be about ſix inches over, or indeed ſomewhat more for thoſe longer Glaſſes. It would be convenient alſo, and not very chargeable, to have four or five ſeveral Tools; as one for all Glaſſes between an inch and a foot, one for all Glaſſes between a foot and ten foot long, another for all between ten and an hundred, a fourth for all between a hundred and a thouſand foot long; and if Curioſity ſhall ever proceed ſo far, one for all lengths between a thouſand and ten thouſand foot long; for indeed the principle is ſuch, that ſuppoſing the *Mandrils* well made, and of a good length, and ſuppoſing great care be uſed in working and poliſhing them, I ſee no reaſon, but that a Glaſs of a thouſand, nay of ten thouſand foot long, may be as well made as one of ten; for the reaſon is the ſame, ſuppoſing the *Mandrils* and Tools be made ſufficiently ſtrong, ſo that they cannot bend; and ſuppoſing the Glaſs, out of which they are wrought, be capable of ſo great a regularity in its parts as to refraction: this hollow *Cylinder* K is to contain the Sand, and by being drove round very quick to and fro by means of a ſmall Wheel, which may be mov'd with ones foot, ſerves to grind the Glaſs: The other *Mandril* is ſhap'd like this, but it has an even neck inſtead of a taper one, and runs in a Collar, that by the help of a Screw, and a joynt made like M in the Figure, it can be ſtill adjuſtned to the wearing or waſting neck: into the end of this *Mandril* is ſcrewed a Chock N, on which with Cement or Glew is faſtned the piece of Glaſs Q that is to be form'd; the middle of which Glaſs is to be plac'd juſt on the edge of the Ring, and the Lath O P is to be ſet and fixt (by means of certain pieces and ſcrews, the manner whereof will be ſufficiently evidenc'd by the Figure) in ſuch an Angle as is requiſite to the forming of ſuch a Sphere as the Glaſs is deſign'd to be of; the geometrical ground of which being ſufficiently plain, though not heeded before, I ſhall, for brevities ſake, paſs over. This laſt *Mandril* is to be made (by means of the former, or ſome other Wheel) to run round very ſwift alſo, by which two croſs motions the Glaſs cannot chuſe (if care be us'd) but be wrought into a moſt exactly ſpherical Surface.

But becauſe we are certain, from the Laws of refraction *(which I I have experimentally found to be ſo, by an Inſtrument I ſhall preſently deſcribe) that* the lines of the angles of Incidence are proportionate to the lines of the angles of Refraction, *therefore if Glaſſes could be made of thoſe kind of Figures, or ſome other, ſuch as the moſt incomparable* Des Cartes *has invented, and demonſtrated in his Philoſophical and Mathematical Works, we might hope for a much greater perfection of Opticks then can be rationally expected from ſpherical ones; for though,* cæteris paribus, *we find, that the larger the* Teleſcope *Object Glaſſes are, and the ſhorter thoſe of the* Microſcope, *the better they magnifie, yet both of them,*

beſide

beside such determinate dimensions, are by certain inconveniences rendred unuseful; for it will be exceeding difficult *to make and* manage *a Tube above an* hundred foot long, *and it will be as difficult to* inlighten *an Object less then an hundred part of an inch distant from the Object Glass.*

I have not as yet made any attempts of that kind, though I know two or three wayes, which, as far as I have yet considered, seem very probable, and may invite me to make a tryal as soon as I have an opportunity, of which I may hereafter perhaps acquaint the world. In the Interim, I shall describe the Instrument I even now mention'd, by which the refraction *of all kinds of Liquors may be most exactly measur'd, thereby to give the curious an opportunity of making what further tryals of that kind they shall think requisite to any of their intended tryals; and to let them see that the laws of Refraction are not only notional.*

The Instrument consisted of five Rulers, or long pieces placed together, after the manner exprest in the second Figure of the first *Scheme*, where A B denotes a straight piece of wood about six foot and two inches long, about three inches over, and an inch and half thick, on the back side of which was hung a small plummet by a line stretcht from top to bottom, by which this piece was set exactly upright, and so very firmly fixt; in the middle of this was made a hole or center, into which one end of a hollow cylindrical brass Box C C, fashion'd as I shall by and by describe, was plac'd, and could very easily and truly be mov'd to and fro; the other end of this Box being put into, and moving in, a hole made in a small arm D D; into this box was fastned the long Ruler E F, about three foot and three or four inches long, and at three foot from the above mention'd Centers P P was a hole E, cut through, and cross'd with two small threads, and at the end of it was fixt a small sight G, and on the back side of it was fixt a small Arm H, with a Screw to fix it in any place on the Ruler L M; this Ruler L M was mov'd on the Center B (which was exactly three foot distance from the middle Center P) and a line drawn through the middle of it L M, was divided by a Line of cords into some sixty degrees, and each degree was subdivided into minutes, so that putting the cross of the threads in E upon any part of this divided line, I presently knew what Angle the two Rules A B and E F made with each other, and by turning the Screw in H, I could fix them in any position. The other Ruler also R S was made much after the same manner, only it was not fixt to the hollow cylindrical Box, but, by means of two small brass Armes or Ears, it mov'd on the Centers of it; this also, by means of the cross threads in the hole S, and by a Screw in K, could be fastned on any division of another line of cords of the same radius drawn on N O. And so by that means, the Angle made by the two Rulers, A B and R S, was also known. The Brass box C C in the middle was shap'd very much like the Figure X, that is, it was a cylindrical Box stopp'd close at either end, off of which a part both of the sides and bottomes was cut out, so

that

that the Box, when the Pipe and that was joyne d to it, would contain the Water when fill'd half full, and would likewise, without running over, indure to be inclin'd to an Angle , equal to that of the greatest refraction of Water, and no more, without running over. The Ruler E F was fixt very fast to the Pipe V, so that the Pipe V directed the length of the Ruler E F, and the Box and Ruler were mov'd on the Pin T T, so as to make any desirable Angle with the Ruler A B. The bottom of this Pipe V was stop'd with a small piece of exactly plain Glass , which was plac'd exactly perpendicular to the Line of direction, or *Axis* of the Ruler E F. The Pins also T T were drill'd with small holes through the *Axis*, and through those holes was stretcht and fastned a small Wire. There was likewise a small Pipe of Tin loosly put on upon the end of V, and reaching down to the sight G ; the use of which was only to keep any false Rayes of light from passing through the bottom of V, and only admitting such to pass as pierced through the sight G: All things being placed together in the manner describ'd in the Figure ; that is, the Ruler A B being fixt perpendicular, I fill'd the Box C C with Water, or any other Liquor, whose refraction I intended to try , till the Wire passing through the middle of it were just covered : then I moved and fixt the Ruler F E at any assignable Angle, and placed the flame of a Candle just against the sight G ; and looking through the sight I, I moved the Ruler R S to and fro, till I perceived the light passing through G to be covered, as 'twere, or divided by the dark Wire passing through P P: then turning the Screw in K, I fixt it in that posture: And through the hole S, I observed what degree and part of it was cut by the cross threads in S. And this gave me the Angle of Inclination, A P S answering to the Angle of Refraction B P E : for the surface of the Liquor in the Box will be alwayes horizontal , and consequently A B will be a perpendicular to it ; the Angle therefore A P S will measure, or be the Angle of Inclination in the Liquor ; next E P B must be the Angle of Refraction, for the Ray that passes through the sight G, passes also perpendicularly through the Glass *Diaphragme* at F, and consequently also perpendicularly through the lower surface of the Liquor contiguous to the Glass, and therefore suffers no refraction till it meet with the horizontal surface of the Liquor in C C, which is determined by the two Angles.

By means of this Instrument I can with little trouble, *and a very small quantity of any* Liquor, *examine, most accurately, the* refraction *of it , not only for one inclination, but for all*; *and thereby am inabled to make very accurate Tables*; *several of which I have also experimentally made, and find, that* Oyl of Turpentine *has a much greater Refraction then* Spirit of Wine , *though it be* lighter ; *and that* Spirit of Wine *has a greater Refraction then* Water, *though it be lighter also* ; *but that* salt Water *also has a greater Refraction then* fresh, *though it be* heavier : *but* Allum water *has a less refraction then common* Water, *though heavier also. So that it seems, as to the* refraction *made in a Liquor, the* speci-

 fick

fick gravity *is of no efficacy. By this I have also found, that look what* proportion *the* Sine *of the Angle of one* Inclination *has to the* Sine *of the Angle of* Refraction, *correspondent to it, the same* proportion *have all the* Sines *of other Inclinations to the* Sines *of their appropriate Refractions.*

My way for measuring how much a Glass magnifies an Object, plac'd at a convenient distance from my eye, is this. Having rectifi'd the *Microscope*, to see the desir'd Object through it very distinctly, at the same time that I look upon the Object through the Glass with one eye, I look upon other Objects at the same distance with my other bare eye; by which means I am able, by the help of a *Ruler* divided into inches and small parts, and laid on the *Pedestal* of the *Microscope*, to cast, as it were, the magnifi'd appearance of the Object upon the Ruler, and thereby exactly to measure the Diameter it appears of through the Glass, which being compar'd with the Diameter it appears of to the naked eye, will easily afford the quantity of its magnifying.

The *Microscope*, which for the most part I made use of, was shap'd much like that in the sixth Figure of the first *Scheme*, the Tube being for the most part not above six or seven inches long, though, by reason it had four Drawers, it could very much be lengthened, as occasion required; this was contriv'd with three Glasses; a small Object Glass at A, a thinner Eye Glass about B, and a very deep one about C: this I made use of only when I had occasion to see much of an Object at once; the middle Glass conveying a very great company of radiating Pencils, which would go another way, and throwing them upon the deep Eye Glass. But when ever I had occasion to examine the small parts of a Body more accurately, I took out the middle Glass, and only made use of one Eye Glass with the Object Glass, for always the fewer the Refractions are, the more bright and clear the Object appears. And therefore 'tis not to be doubted, but could we make a *Microscope* to have one only refraction, it would, *ceteris paribus*, far excel any other that had a greater number. And hence it is, that if you take a very clear piece of a broken *Venice* Glass, and in a Lamp draw it out into very small hairs or threads, then holding the ends of these threads in the flame, till they melt and run into a small round Globul, or drop, which will hang at the end of the thread; and if further you stick several of these upon the end of a stick with a little sealing Wax, so as that the threads stand upwards, and then on a Whetstone first grind off a good part of them, and afterward on a smooth Metal plate, with a little Tripoly, rub them till they come to be very smooth; if one of these be fixt with a little soft Wax against a small needle hole, prick'd through a thin Plate of Brass, Lead, Pewter, or any other Metal, and an Object, plac'd very near, be look'd at through it, it will both magnifie and make some Objects more distinct then any of the great *Microscopes*. But because these, though exceeding easily made, are yet very troublesome to be us'd, because of their smalness, and the nearness of the Object; therefore to prevent both these, and yet have only two Refractions, I provided me a Tube of Brass, shap'd much like that in the fourth Figure of the first *Scheme*; into the smaller end of this I fixt with Wax a good *plano con-*

vex Object Glaſs,with the convex ſide towards the Object, and into the bigger end I fixt alſo with wax a pretty large plano *Convex* Glaſs, with the *convex* ſide towards my eye, then by means of the ſmall hole by the ſide, I fill'd the intermediate ſpace between theſe two Glaſſes with very clear Water, and with a Screw ſtopp'd it in; then putting on a Cell for the Eye, I could perceive an Object more bright then I could when the intermediate ſpace was only fill'd with Air,but this, for other inconveniences, I made but little uſe of.

My way for fixing both the Glaſs and Object to the Pedeſtal moſt conveniently was thus: Upon one ſide of a round Pedeſtal A B, in the ſixth Figure of the firſt *Scheme*,was fixt a ſmall Pillar C C, on this was fitted a ſmall Iron Arm D, which could be mov'd up and down, and fixt in any part of the Pillar,by means of a ſmall Screw E; on the end of this Arm was a ſmall Ball fitted into a kind of ſocket F, made in the ſide of the Braſs Ring G, through which the ſmall end of the Tube was ſcrew'd; by means of which contrivance I could place and fix the Tube in what poſture I deſir'd (which for many Obſervations was exceeding neceſſary) and adjuſten it moſt exactly to any Object.

For placing the Object,I made this contrivance; upon the end of a ſmall braſs Link or Staple H H, I ſo faſtned a round Plate I I, that it might be turn'd round upon its Center K, and going pretty ſtiff, would ſtand fixt in any poſture it was ſet; on the ſide of this was fixt a ſmall Pillar P, about three quarters of an inch high, and through the top of this was thruſt a ſmall Iron pin M, whoſe top juſt ſtood over the Center of the Plate; on this top I fixt a ſmall Object, and by means of theſe contrivances I was able to turn it into all kind of poſitions, both to my Eye and the Light; for by moving round the ſmall Plate on its center, I could move it one way, and by turning the Pin M, I could move it another way, and this without ſtirring the Glaſs at all, or at leaſt but very little: the Plate likewiſe I could move to and fro to any part of the Pedeſtal (which in many caſes was very convenient) and fix it alſo in any Poſition, by means of a Nut N, which was ſcrew'd on upon the lower part of the Pillar C C. All the other Contrivances are obvious enough from the draught,and will need no deſcription

Now though this were the Inſtrument I made moſt uſe of, yet I have made ſeveral other Tryals with other kinds of Microſcopes, *which both for* matter *and* form *were very different from common ſpherical Glaſſes. I have made a* Microſcope *with one piece of Glaſs, both whoſe ſurfaces were* plains. *I have made another only with a* plano concave, *without any kind of reflection, divers alſo by means of* reflection. *I have made others of* Waters, Gums, Reſins, Salts, Arſenick, Oyls, *and with divers other* mixtures *of* watery *and* oyly Liquors. *And indeed the ſubject is capable of a great variety; but I find generally none more uſeful then that which is made with* two Glaſſes, *ſuch as I have already deſcrib'd.*

What

What the things are I obſerv'd, the following deſcriptions will manifeſt; in brief, they were either exceeding ſmall Bodies, or exceeding ſmall Pores, or exceeding ſmall Motions, ſome of each of which the Reader will find in the following Notes, and ſuch, as I preſume, (many of them at leaſt) will be new, and perhaps not leſs ſtrange: Some ſpecimen of each of which Heads the Reader will find in the ſubſequent delineations, and indeed of ſome more then I was willing there ſhould be; which was occaſioned by my firſt Intentions to print a much greater number then I have ſince found time to compleat. Of ſuch therefore as I had, I ſelected only ſome few of every Head, which for ſome particulars ſeem'd moſt obſervable, rejecting the reſt as ſuperfluous to the preſent Deſign.

What each of the delineated Subjects are, the following deſcriptions annext to each will inform, of which I ſhall here, only once for all, add, That in divers of them the Gravers have pretty well follow'd my directions and draughts; and that in making of them, I indeavoured (as far as I was able) firſt to diſcover the true appearance, and next to make a plain repreſentation of it. This I mention the rather, becauſe of theſe kind of Objects there is much more difficulty to diſcover the true ſhape, then of thoſe viſible to the naked eye, the ſame Object ſeeming quite differing, in one poſition to the Light, from what it really is, and may be diſcover'd in another. And therefore I never began to make any draught before by many examinations in ſeveral lights, and in ſeveral poſitions to thoſe lights, I had diſcover'd the true form. For it is exceeding difficult in ſome Objects, to diſtinguiſh between a prominency and a depreſſion, between a ſhadow and a black ſtain, or a reflection and a whiteneſs in the colour. Beſides, the tranſparency of moſt Objects renders them yet much more difficult then if they were opacous. The Eyes of a Fly in one kind of light appear almoſt like a Lattice, drill'd through with abundance of ſmall holes; which probably may be the Reaſon, why the Ingenious Dr. Power ſeems to ſuppoſe them ſuch. In the Sunſhine they look like a Surface cover'd with golden Nails; in another poſture, like a Surface cover'd with Pyramids; in another with Cones; and in other poſtures of quite other ſhapes; but that which exhibits the beſt, is the Light collected on the Object, by thoſe means I have already deſcrib'd.

And this was undertaken in prosecution of the Design, which the ROYAL SOCIETY *has propos'd to it self. For the Members of the Assembly having before their eys so many* fatal *Instances of the errors and falshoods, in which the greatest part of mankind has so long wandred, because they rely'd upon the strength of humane Reason alone, have begun anew to correct all* Hypotheses *by sense, as Seamen do their* dead Reckonings *by* Cœlestial Observations; *and to this purpose it has been their principal indeavour to* enlarge *&* strengthen *the* Senses *by* Medicine, *and by such* outward Instruments *as are proper for their particular works. By this means they find some reason to suspect, that those effects of Bodies, which have been commonly attributed to* Qualities, *and those confess'd to be* occult, *are perform'd by the small* Machines *of Nature, which are not to be discern'd without these helps, seeming the meer products of* Motion, Figure, *and* Magnitude; *and that the* Natural Textures, *which some call the* Plastick faculty, *may be made in* Looms, *which a greater perfection of Opticks may make discernable by these Glasses; so as now they are no more puzzled about them, then the vulgar are to conceive, how* Tapestry *or* flowred Stuffs *are woven. And the ends of all these Inquiries they intend to be the* Pleasure *of Contemplative minds, but above all, the* ease and dispatch *of the labours of mens hands. They do indeed neglect no opportunity to bring all the* rare *things of Remote Countries within the compass of their knowledge and practice. But they still acknowledg their* most useful *Informations to arise from* common *things, and from* diversifying *their most* ordinary *operations upon them. They do not wholly reject Experiments of meer* light *and* theory; *but they principally aim at such, whose Applications will* improve and facilitate *the present way of* Manual Arts. *And though some men, who are perhaps taken up about less honourable Employments, are pleas'd to censure their proceedings, yet they can shew more* fruits *of their first three years, wherein they have assembled, then any other* Society *in* Europe *can for a much larger space of time. 'Tis true, such undertakings as theirs do commonly meet with small incouragement, because men are generally rather taken with the* plausible *and* discursive, *then the* real *and the solid part of Philosophy; yet by the good fortune of their institution, in an Age of all others the most* inquisitive, *they have been assisted by the* contribution *and* presence *of very many of the chief* Nobility *and* Gentry,

and others, who are some of the most considerable *in their several Professions. But that that yet farther convinces me of the* Real esteem *that the more se-*rious *part of men have of this* Society, *is, that several* Merchants, *men who act in earnest (whose Object is* meum & tuum, *that great* Rudder *of humane affairs) have adventur'd considerable sums of* Money, *to put in practice what some of our Members have contrived, and have continued* stedfast *in their good opinions of such Indeavours, when not one of a hundred of the vulgar have believed their undertakings feasable. And it is also fit to be added, that they have one advantage peculiar to themselves, that very many of their number are* men of Converse and Traffick; *which is a good Omen, that their attempts will bring Philosophy from* words to action, *seeing the men of Business have had so great a share in their first foundation.*

And of this kind I ought not to conceal one particular Generosity, *which more nearly concerns my self. It is the* munificence *of* Sir John Cutler, *in endowing a Lecture for the promotion of* Mechanick Arts, *to be governed and directed by This* Society. *This* Bounty *I mention for the* Honourableness *of the thing it self, and for the expectation which I have of the* efficacy *of the* Example; *for it cannot now be objected to them, that their Designs will be esteemed* frivolous *and* vain, *when they have such a* real Testimony *of the* Approbation *of a* Man *that is such an* eminent Ornament *of this renowned City, and one, who, by the* Variety, *and the* happy Success, *of his negotiations, has given evident proofs, that he is not easie to be deceiv'd. This Gentleman has well observ'd, that the* Arts *of life have been too long* imprison'd *in the dark shops of Mechanicks themselves, & there* hindred from growth, *either by ignorance, or self-interest: and he has bravely* freed *them from these* inconveniences: *He hath not only obliged* Tradesmen, *but* Trade *it self: He has done a work that is worthy of* London, *and has taught the chief City of Commerce in the world the right way how Commerce is to be improv'd. We have already seen many other great signs of Liberality and a large mind, from the same hand: For by his* diligence *about the* Corporation for the Poor; *by his honorable* Subscriptions *for the rebuilding of St.* Paul's; *by his chearful* Disbursment *for the replanting of* Ireland, *and by many other such* publick works, *he has shewn by what means he indeavours to* establish *his Memory; and now by this last gift he has done that, which became one of the* wisest Citizens

of

of our Nation to accomplish, seeing one of the wiseſt of our Stateſmen,the Lord Verulam,*firſt propounded it.*

But to return to my Subject, from a digreſſion, which, I hope,my Reader will pardon me, ſeeing the Example is ſo rare that I can make no more ſuch digreſſions. If theſe my firſt Labours ſhall be any wayes uſeful to inquiring men, I muſt attribute the incouragement and promotion of them to a very Reverend *and* Learned Perſon, *of whom this ought in juſtice to be ſaid,* That there is ſcarce any one Invention, which this Nation has produc'd in our Age, but it has ſome way or other been ſet forward by his aſſiſtance. *My Reader,I believe,will quickly gheſs, that it is* Dr. Wilkins *that I mean.He is indeed a man born for the* good *of* mankind,*and for the* honour *of his* Couutry. *In the* ſweetneſs *of whoſe* behaviour,*in the* calmneſs *of his* mind, *in the* unbounded goodneſs *of his* heart, *we have an evident Inſtance, what the true and the* primitive unpaſſionate Religion *was, before it was* ſowred *by particular* Factions. *In a word, his* Zeal *has been ſo* conſtant *and* effectual *in advancing all good and profitable* Arts,*that as one of the Antient* Romans *ſaid of* Scipio, That he thanked God that he was a *Roman* ; becauſe whereever *Scipio* had been born, there had been the ſeat of the Empire of the world : *So may I thank God, that* Dr. Wilkins *was an* Engliſhman, *for whereever he had lived, there had been the chief Seat of* generous Knowledge *and* true Philoſophy. *To the truth of this,there are ſo many worthy men living that will ſubſcribe, that I am confident, what I have here ſaid, will not be look'd upon, by any ingenious Reader, as a* Panegyrick, *but only as a* real teſtimony.

By the Advice of this Excellent man *I firſt ſet upon this Enterpriſe, yet ſtill came to it with much* Reluctancy,*becauſe I was to follow the footſteps of ſo eminent a Perſon as* Dr. Wren , *who was the firſt that attempted any thing of this nature ; whoſe original draughts do now make one of the Ornaments of that great Collection of Rarities in the* Kings Cloſet. *This* Honor, *which his firſt beginnings of this kind have receiv'd, to be admitted into the moſt famous place of the world,did not ſo much* incourage, *as the* hazard *of coming after* Dr. Wren *did* affright *me ; for of him I muſt affirm, that, ſince the time of* Archimedes, *there ſcarce ever met in one man, in ſo*

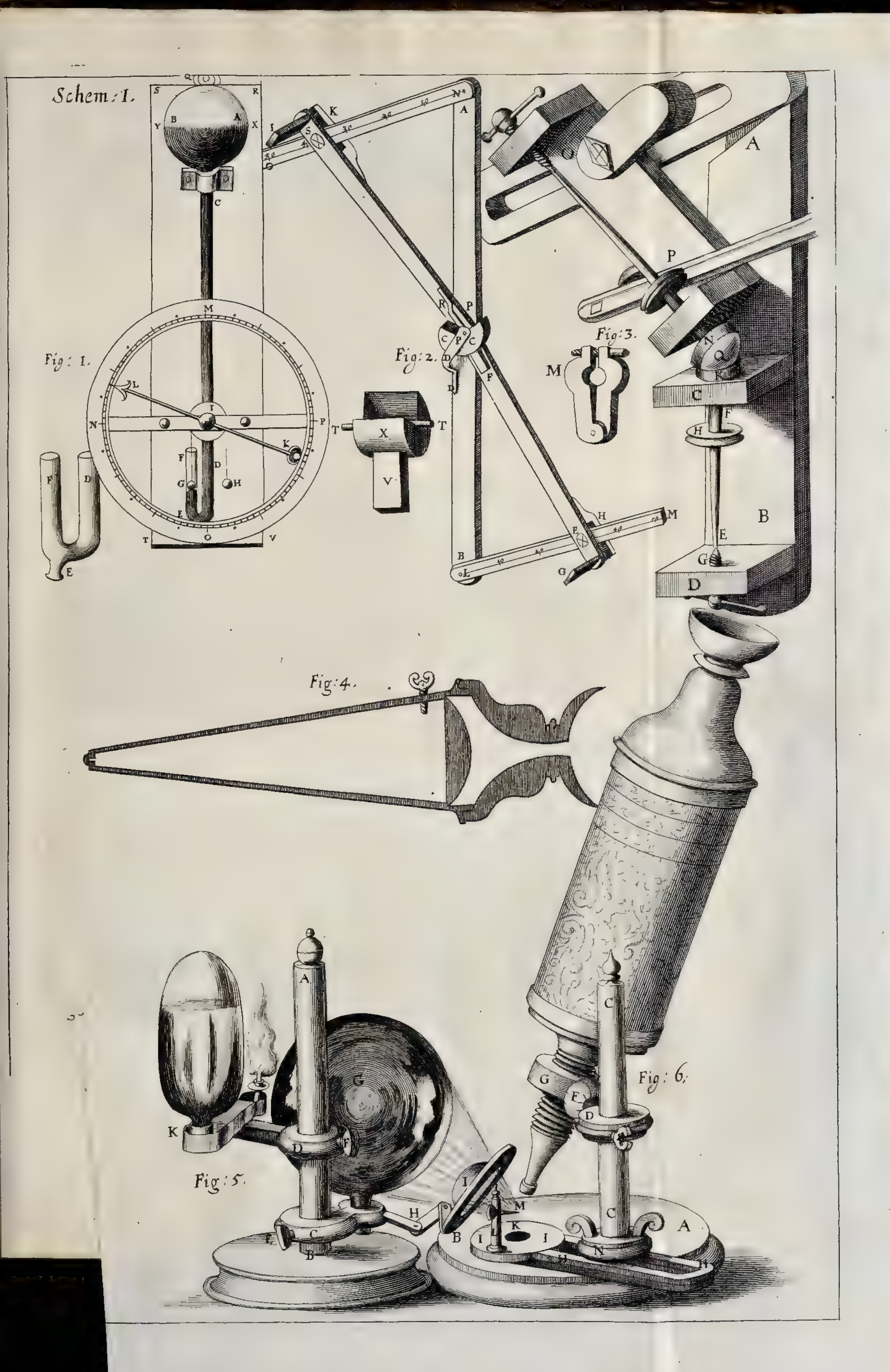
great

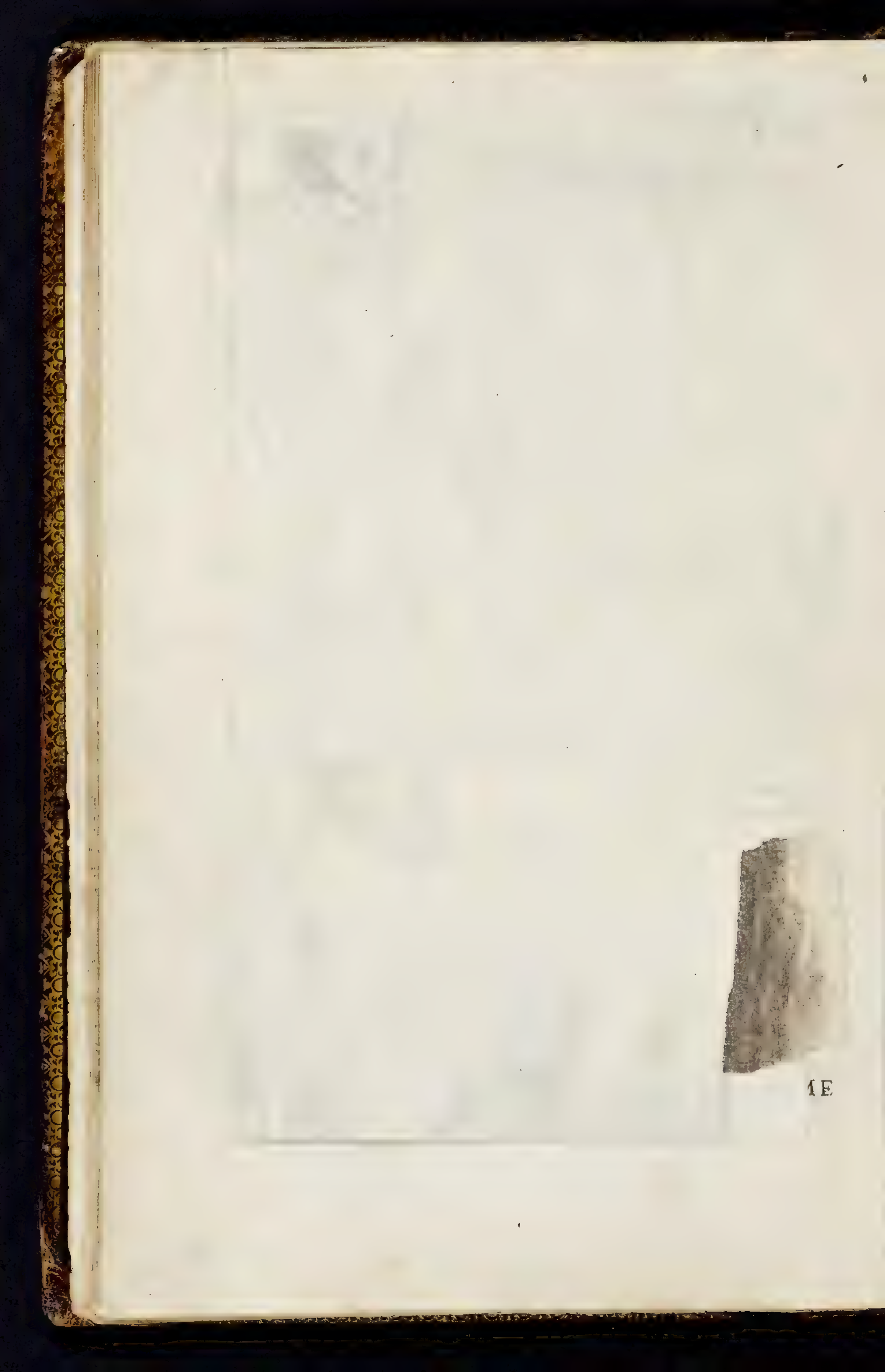
great a perfection, such a Mechanical Hand, *and so* Philosophical *a* Mind.

But at last, being assured both by Dr. Wilkins, *and* Dr. Wren *himself, that he had given over his intentions of prosecuting it, and not finding that there was any else design'd the pursuing of it, I set upon this undertaking, and was not a little incourag'd to proceed in it, by the Honour the* Royal Society *was pleas'd to favour me with, in approving of those draughts (which from time to time as I had an opportunity of describing) I presented to them. And particularly by the Incitements of divers of those Noble and excellent Persons of it, which were my more especial Friends, who were not less urgent with me for the publishing, then for the prosecution of them.*

After I had almost compleated these Pictures and Observations (having had divers of them ingraven, and was ready to send them to the Press) I was inform'd, that the Ingenious Physitian Dr. Henry Power *had made several* Microscopical *Observations, which had I not afterwards, upon our interchangably viewing each others Papers, found that they were for the most part differing from mine, either in the Subject it self, or in the particulars taken notice of; and that his design was only to print Observations without Pictures, I had even then* suppressed *what I had so far proceeded in. But being further* excited *by several of my Friends, in complyance with their opinions, that it would not be unacceptable to several inquisitive Men, and hoping also, that I should thereby discover something New to the World, I have at length cast in my Mite, into the vast Treasury of* A Philosophical History. *And it is my* hope, *as well as* belief, *that these my* Labours *will be no more comparable to the* Productions *of many other* Natural Philosophers, *who are now every where busie about* greater *things; then my* little Objects *are to be compar'd to the greater and more beautiful* Works of Nature, *A Flea, a Mite, a Gnat, to an Horse, an Elephant, or a Lyon.*

SOME


Schem: I.
Fig: 1.
Fig: 2.
Fig: 3.
Fig: 4.
Fig: 5.
Fig: 6.





MICROGRAPHIA, OR SOME Physiological Descriptions OF MINUTE BODIES, MADE BY MAGNIFYING GLASSES; WITH OBSERVATIONS and INQUIRIES thereupon.

Observ. I. *Of the Point of a sharp small Needle.*

AS in *Geometry*, the most natural way of beginning is from a Mathematical *point*; so is the same method in Observations and *Natural history* the most genuine, simple, and instructive. We must first endevour to make *letters*, and draw *single* strokes true, before we venture to write whole *Sentences*, or to draw large *Pictures*. And in *Physical* Enquiries, we must endevour to follow Nature in the more *plain* and *easie* ways she treads in the most *simple* and *uncompounded bodies*, to trace her steps, and be acquainted with her manner of walking there, before we venture our selves into the multitude of *meanders* she has in *bodies of a more complicated* nature; lest, being unable to distinguish and judge of our way, we quickly lose both *Nature* our Guide, and *our selves* too, and are left to wander in the *labyrinth* of groundless opinions; wanting both *judgment*, that *light*, and *experience*, that *clew*, which should direct our proceedings.

Schem.2. Fig.1.

We will begin these our Inquiries therefore with the Observations of Bodies of the most *simple nature* first, and so gradually proceed to those of a more *compounded* one. In prosecution of which method, we shall begin with a *Physical point*; of which kind the *Point of a Needle* is commonly reckon'd for one; and is indeed, for the most part, made so sharp, that the naked eye cannot distinguish any parts of it: It very easily pierces, and makes its way through all kind of bodies softer then it self: But if view'd with a very good *Microscope*, we may find that the *top* of a Needle (though as to the

sense

ſenſe very *ſharp)* appears a *broad,blunt*, and very *irregular* end; not reſembling a Cone, as is imagin'd, but onely a piece of a tapering body, with a great part of the top remov'd, or deficient. The Points of Pins are yet more blunt, and the Points of the moſt curious Mathematital Inſtruments do very ſeldome arrive at ſo great a ſharpneſs; how much therefore can be built upon demonſtraticns made onely by the productions of the Ruler and Compaſſes, he will be better able to conſider that ſhall but view thoſe *points* and *lines* with a *Microſcope*.

Now though this point be commonly accounted the ſharpeſt (whence when we would expreſs the ſharpneſs of a point the moſt *ſuperlatively*, we ſay, As ſharp as a Needle) yet the *Microſcope* can afford us hundreds of Inſtances of Points many thouſand times ſharper: ſuch as thoſe of the *hairs*, and *briſtles*, and *claws* of multitudes of *Inſects*; the *thorns*, or *crooks*, or *hairs* of *leaves*, and other ſmall vegetables; nay, the ends of the *ſtiriæ* or ſmall *parallelipipeds* of *Amianthus*, and *alumen plumoſum*; of many of which, though the Points are ſo ſharp as not to be viſible, though view'd with a *Microſcope* (which magnifies the Object, in bulk, above a million of times) yet I doubt not, but were we able *practically* to make *Microſcopes* according to the *theory* of them, we might find hills, and dales,and pores, and a ſufficient bredth, or expanſion, to give all thoſe parts elbow-room, even in the blunt top of the very Point of any of theſe ſo very ſharp bodies. For certainly the *quantity* or extenſion of any body may be *Diviſible in infinitum*, though perhaps not the *matter*.

But to proceed: The Image we have here exhibited in the firſt Figure, was the top of a ſmall and very ſharp Needle, whoſe point *a a* nevertheleſs appear'd through the *Microſcope* above a quarter of an inch broad, not round nor flat, but *irregular* and *uneven*; ſo that it ſeem'd to have been big enough to have afforded a hundred armed Mites room enough to be rang'd by each other without endangering the breaking one anothers necks, by being thruſt off on either ſide. The ſurface of which, though appearing to the naked eye very ſmooth,could not nevertheleſs hide a multitude of holes and ſcratches and ruggedneſſes from being diſcover'd by the *Microſcope* to inveſt it, ſeveral of which inequalities (as A,B,C, ſeem'd *holes* made by ſome ſmall ſpecks of *Ruſt*; and D ſome *adventitious body*, that ſtuck very cloſe to it) were *caſual*. All the reſt that roughen the ſurface, were onely ſo many marks of the rudeneſs and bungling of *Art*. So unaccurate is it, in all its productions, even in thoſe which ſeem moſt neat, that if examin'd with an organ more acute then that by which they were made, the more we ſee of their *ſhape*, the leſs appearance will there be of their *beauty*: whereas in the works of *Nature*, the deepeſt Diſcoveries ſhew us the greateſt Excellencies. An evident Argument, that he that was the Author of all theſe things, was no other then *Omnipotent*; being able to include as great a variety of parts and contrivances in the yet ſmalleſt Diſcernable Point, as in thoſe vaſter bodies (which comparatively are called alſo Points) ſuch as the *Earth*, *Sun*, or *Planets*. Nor need it ſeem ſtrange that the Earth it ſelf may be by an *Analogie* call'd a Phyſical Point: For as its body,though now

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$\frac{1}{20}$ pollicis Ang: Or of an inch

Fig: 1

a

b

D C

a

b

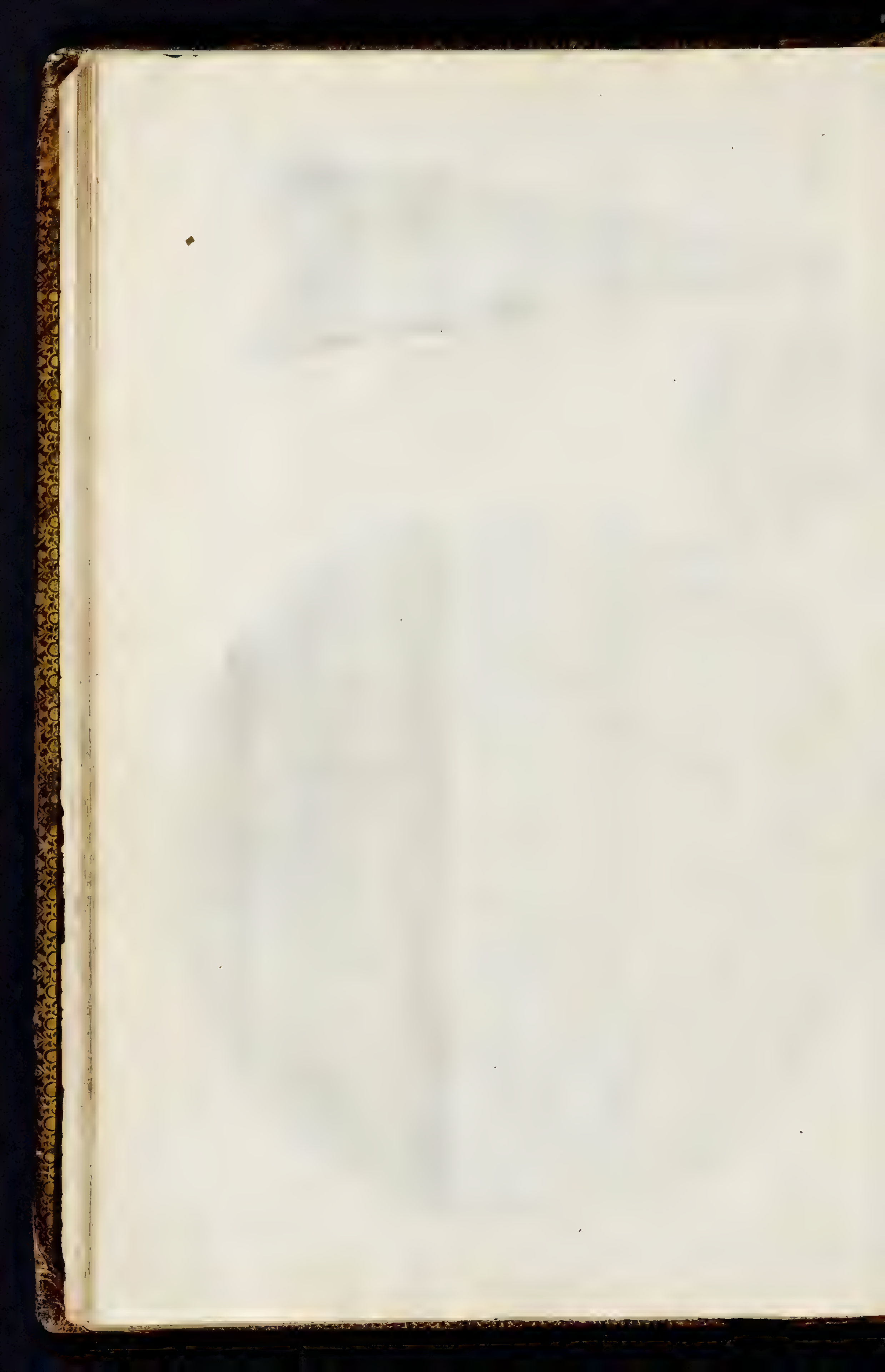
a

b

⊙ A

$\frac{1}{16}$ poll: Ang: or of an inch

Fig: 2: a.



ſo near us as to fill our eys and fancies with a ſenſe of the vaſtneſs of it, may by a little Diſtance, and ſome convenient *Diminiſhing* Glaſſes, be made vaniſh into a ſcarce viſible Speck, or Point (as I have often try'd on the *Moon*, and (when not too bright) on the *Sun* it ſelf.) So, could a Mechanical contrivance ſuccesfully anſwer our *Theory*, we might ſee the leaſt ſpot as big as the Earth it ſelf; and Diſcover, as *Des Cartes* alſo conjectures, as great a variety of bodies in the *Moon*, or *Planets*, as in the *Earth*.

Diop. ch. 10. § 9.

But leaving theſe Diſcoveries to future Induſtries, we ſhall proceed to add one Obſervation more of a *point* commonly ſo call'd, that is, the mark of a *full ſtop*, or *period*. And for this purpoſe I obſerved many both *printed* ones and *written*; and among multitudes I found *few* of them more *round* or *regular* then this which I have delineated in the third figure of the ſecond Scheme, but *very many* abundantly *more disfigur'd*; and for the moſt part if they ſeem'd equally round to the eye, I found thoſe points that had been made by a *Copper-plate*, and Roll-preſs, to be as misſhapen as thoſe which had been made with *Types*, the moſt curious and ſmothly *engraven ſtrokes* and *points*, looking but as ſo many *furrows* and *holes*, and their *printed impreſſions*, but like *ſmutty daubings* on a matt or uneven floor with a blunt extinguiſht brand or ſtick's end. And as for *points* made with a *pen* they were much *more rugged* and *deformed*. Nay, having view'd certain pieces of exceeding curious writing of the kind (one of which in the bredth of a *two-pence* compris'd *the Lords prayer*, *the Apoſtles Creed*, *the ten Commandments*, *and about half a dozen verſes beſides of the Bible*, whoſe *lines* were ſo *ſmall* and *near together*, that I was unable to *number* them with my *naked eye*, a very ordinary *Microſcope*, I had then about me, inabled me to ſee that what the Writer of it had aſſerted was *true*, but withall diſcover'd of what pitifull *bungling ſcribbles* and *ſcrawls* it was compos'd, *Arabian* and *China characters* being almoſt as well ſhap'd; yet thus much I muſt ſay for the Man, that it was for the moſt part *legible* enough, though in ſome places there wanted a good *fantſy* well *prepoſeſt* to help one through. If this manner of *ſmall writing* were made *eaſie* and *practicable* (and I think I know ſuch a one, but have never yet made tryal of it, whereby one might be inabled to write *a great deale* with *much eaſe*, and *accurately* enough in a very *little roome*) it might be of very good uſe to convey *ſecret Intelligence* without any danger of *Diſcovery* or *miſtruſting*. But to come again to the point. The *Irregularities* of it are cauſed by three or four *coadjutors*, one of which is, the *uneven ſurface* of the *paper*, which at beſt appears no ſmother then a very courſe piece of *ſhag'd cloth*, next the *irregularity of the Type* or *Ingraving*, and a third is the *rough Daubing* of the *Printing-Ink* that lies upon the inſtrument that makes the impreſſion, to all which, add the *variation* made by the Different *lights* and *ſhadows*, and you may have ſufficient reaſon to gheſs that a *point* may appear much more *ugly* then *this*, which I have here preſented, which though it appear'd through the *Microſcope gray*, like a great ſplatch of *London* dirt, about three inches over; yet to the *naked eye* it was *black*, and no bigger then that in the midſt of the Circle A. And could I have found

found Room in this Plate to have inserted an O you should have seen that the *letters* were not more distinct then the *points* of Distinction, nor a *drawn circle* more exactly *so*, then we have now shown a *point* to be a *point*.

Observ. II. *Of the Edge of a Razor.*

Schem.2. Fig. 2.

THe sharpest *Edge* hath the same kind of affinity to the sharpest *Point* in Physicks, as a *line* hath to a *point* in Mathematicks; and therefore the Treaty concerning this, may very properly be annexed to the former. A Razor doth appear to be a Body of a very neat and curious aspect, till more closely viewed by the *Microscope*, and there we may observe its very Edge to be of all kind of shapes, except what it should be. For examining that of a very sharp one, I could not find that any part of it had any thing of sharpness in it; but it appear'd a rough surface of a very considerable bredth from side to side, the narrowest part not seeming thinner then the back of a pretty thick Knife. Nor is't likely that it should appear any otherwise, since as we just now shew'd that a *point* appear'd a *circle*, 'tis rational a *line* should be a *parallelogram*.

Now for the drawing this second Figure (which represents a part of the Edge about half a quarter of an inch long of a Razor well set) I so plac'd it between the Object-glass & the light that there appear'd a reflection from the very Edge, represented by the white line *a b c d e f*. In which you may perceive it to be somewhat sharper then elsewhere about *d*, to be indented or pitted about *b*, to be broader and thicker about *c*, and unequal and rugged about *e*, and pretty even between *a b* and *e f*. Nor was that part of the Edge *g h i k* so smooth as one would imagine so smooth bodies as a Hone and Oyl should leave it; for besides those multitudes of scratches, which appear to have raz'd the surface *g h i k*, and to cross each other every way which are not half of them exprest in the Figure, there were several great and deep scratches, or furrows, such as *g h* and *i k*, which made the surface yet more rugged, caus'd perhaps by some small Dust casually falling on the Hone, or some harder or more flinty part of the Hone it self. The other part of the Razor *l l*, which is polish'd on a grinding-stone, appear'd much rougher then the other, looking almost like a plow'd field, with many parallels, ridges, and furrows, and a cloddy, as 'twere, or an uneven surface: nor shall we wonder at the roughnesses of those surfaces, since even in the most curious wrought Glasses for *Microscopes*, and other Optical uses, I have, when the Sun has shone well on them, discover'd their surface to be variously raz'd or scratched, and to consist of an infinite of small broken surfaces, which reflect the light of very various and differing colours. And indeed it seems impossible by Art to cut the surface of any hard and brittle body smooth, since *Putte*, or even the most curious *Powder* that can be made use of, to polish such a body, must consist of little hard rough particles, and each of them must cut its way, and consequently leave some kind of gutter or

furrows

furrow behind it. And though Nature does ſeem to do it very readily in all kinds of fluid bodies, yet perhaps future obſervators may diſcover even theſe alſo rugged; it being very probable, as I elſewhere ſhew, that fluid bodies are made up of ſmall ſolid particles variouſly and ſtrongly mov'd, and may find reaſon to think there is ſcarce a ſurface *in rerum naturâ* perfectly ſmooth. The black ſpot *m n*, I gheſs to be ſome ſmall ſpeck of ruſt, for that I have oft obſerv'd to be the manner of the working of Corroſive Juyces. To conclude, this Edge and piece of a Razor, if it had been really ſuch as it appear'd through the *Microſcope*, would ſcarcely have ſerv'd to cleave wood, much leſs to have cut off the hair of beards, unleſs it were after the manner that *Lucian* merrily relates *Charon* to have made uſe of, when with a Carpenters Axe he chop'd off the beard of a ſage Philoſopher, whoſe gravity he very cautiouſly fear'd would indanger the overſetting of his Wherry.

Obſerv. III. *Of fine Lawn, or Linnen Cloth.*

Schem. 15. Fig. 3.

THis is another product of Art, A piece of the fineſt Lawn I was able to get, ſo curious that the threads were ſcarce diſcernable by the naked eye, and yet through an ordinary *Microſcope* you may perceive what a goodly piece of *coarſe Matting* it is; what proportionable cords each of its threads are, being not unlike, both in ſhape and ſize, the bigger and coarſer kind of *ſingle Rope-yarn*, wherewith they uſually make *Cables*. That which makes the Lawn ſo tranſparent, is by the *Microſcope*, nay by the naked eye, if attentively viewed, plainly enough evidenced to be the multitude of ſquare holes which are left between the threads, appearing to have much more hole in reſpect of the intercurrent parts then is for the moſt part left in a *lattice-window*, which it does a little reſemble, onely the croſſing parts are round and not flat.

Theſe threads that compoſe this fine contexture, though they are as ſmall as thoſe that conſtitute the finer ſorts of Silks, have notwithſtanding nothing of their gloſſie, pleaſant, and lively reflection. Nay, I have been informed both by the Inventor himſelf, and ſeveral other eye-witneſſes, that though the flax, out of which it is made, has been (by a ſingular art, of that excellent Perſon, and Noble Vertuoſo, M. *Charls Howard*, brother to the *Duke of Norfolk*) ſo curiouſly dreſ'd and prepar'd, as to appear both to the eye and the touch, full as *fine* and as *gloſſie*, and to receive all kinds of colours, as well as Sleave-Silk; yet when this Silken Flax is twiſted into threads, it quite loſeth its former luſter, and becomes as plain and baſe a thread to look on, as one of the ſame bigneſs, made of common Flax.

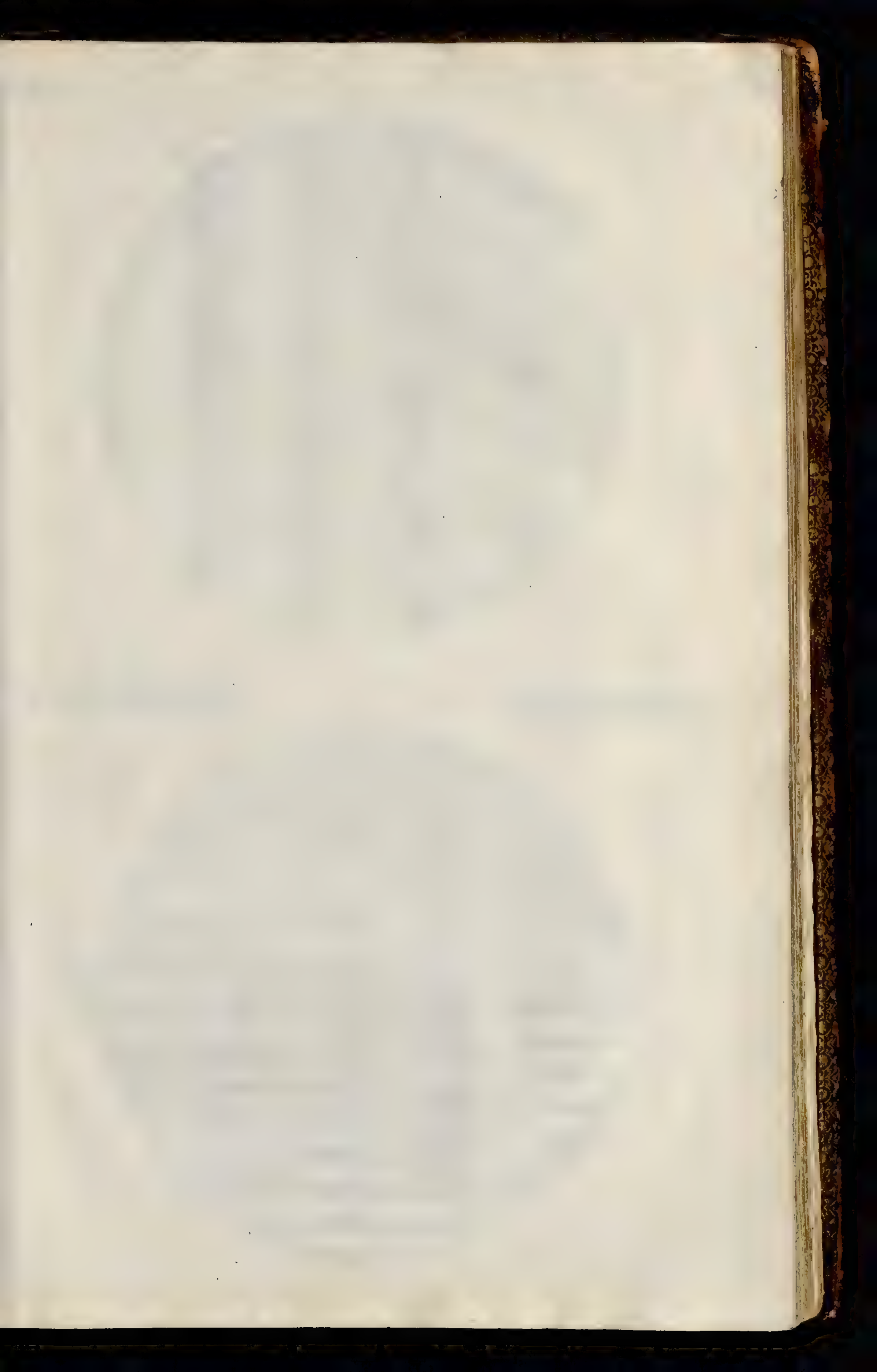
The reaſon of which odd *Phenomenon* ſeems no other then this; that though the curiouſly dreſt Flax has its parts ſo exceedingly ſmall, as to equallize, if not to be much ſmaller then the clew of the Silk-worm, eſpecially in thinneſs, yet the differences between the figures of the conſtituting filaments are ſo great, and their ſubſtances ſo various, that whereas

those of the *Silk* are *small, round, hard, transparent*, and to their bigness proportionably *stiff*, so as each filament preserves its proper *Figure*, and consequently its vivid *reflection* intire, though twisted into a thread, if not too hard; those of Flax are *flat, limber, softer*, and *less transparent*, and in twisting into a thread they joyn, and lie so close together, as to lose their own, and destroy each others particular reflections. There seems therefore three Particulars very requisite to make the so drest Flax appear Silk also when spun into threads. First, that the substance of it should be made more *clear* and *transparent*, Flax retaining in it a kind of opacating brown, or yellow; and the parts of the whitest kind I have yet observ'd with the *Microscope* appearing white, like flaw'd Horn or Glass, rather then clear, like clear Horn or Glass. Next that, the filaments should each of them be *rounded*, if that could be done, which yet is not so very necessary, if the first be perform'd, and this third, which is, that each of the small filaments be *stifned*; for though they be square, or flat, provided they be *transparent* and stiff, much the same appearances must necessarily follow. Now, though I have not yet made trial, yet I doubt not, but that both these proprieties may be also induc'd upon the Flax, and perhaps too by one and the same Expedient, which some trials may quickly inform any ingenious attempter of, who from the use and profit of such an Invention, may find sufficient argument to be prompted to such Inquiries. As for the *tenacity* of the substance of Flax, out of which the thread is made, it seems much inferiour to that of Silk, the one being a *vegetable*, the other an *animal* substance. And whether it proceed from the better concoction, or the more homogeneous constitution of *animal* substances above those of *vegetables*, I do not here determine; yet since I generally find, that *vegetable* substances do not equalize the *tenacity* of *animal*, nor these the *tenacity* of some purified *mineral* substances; I am very apt to think, that the *tenacity* of bodies does not proceed from the *hamous*, or *hooked* particles, as the *Epicureans*, and some modern *Philosophers* have imagin'd; but from the more exact *congruity* of the constituent parts, which are contiguous to each other, and so bulky, as not to be easily separated, or shatter'd, by any small pulls or concussion of heat.

Observ. IV. *Of fine waled Silk, or Taffety.*

Schem. 3. Fig. 1.

THis is the appearance of a piece of very fine Taffety-riband in the bigger magnifying Glass, which you see exhibits it like a very convenient substance to make Bed-matts, or Door-matts of, or to serve for Bee-hives, Corn-scuttles, Chairs, or Corn-tubs, it being not unlike that kind of work, wherewith in many parts in *England*, they make such Utensils of Straw, a little wreathed, and bound together with thongs of Brambles. For in this Contexture, each little filament, fiber, or clew of the Silk-worm, seem'd about the bigness of an ordinary Straw, as appears by the little irregular



Schem: I

Fig: 1

Fig: 3

Fig: 4

A

Fig: 2

C

D

B

regular pieces, *a b*, *c d*, and *e f*; The *Warp*, or the thread that ran crossing the Riband, appear'd like a single Rope of an Inch Diameter; but the *Woof*, or the thread that ran the length of the Riband, appear'd not half so big. Each Inch of six-peny-broad Riband appearing no less then a piece of Matting Inch and half thick, and twelve foot square; a few yards of this, would be enough to floor the long Gallery of the *Loure* at *Paris*. But to return to our piece of Riband: It affords us a not unpleasant object, appearing like a bundle, or wreath, of very clear and transparent *Cylinders*, if the Silk be white, and curiously ting'd; if it be colour'd, each of those small horney *Cylinders* affording in some place or other of them, as vivid a reflection, as if it had been sent from a *Cylinder* of Glass or Horn. In-so-much, that the reflections of Red, appear'd as if coming from so many *Granates*, or *Rubies*. The loveliness of the colours of Silks above those of hairy Stuffs, or Linnen, consisting, as I else-where intimate, chiefly in the transparency, and vivid reflections from the *Concave*, or inner surface of the *transparent Cylinder*, as are also the colours of Precious Stones; for most of the reflections from each of these *Cylinders*, come from the *Concave* surface of the air, which is as 'twere the foil that incompasses the *Cylinder*. The colours with which each of these *Cylinders* are ting'd, seem partly to be superficial, and sticking to the out-sides of them; and partly, to be imbib'd, or sunck into the substance of them: for Silk, seeming to be little else then a dried thread of Glew, may be suppos'd to be very easily relaxt, and softened, by being steeped in warm, nay in cold, if penetrant, juyces or liquors. And thereby those tinctures, though they tinge perhaps but a small part of the substance, yet being so highly impregnated with the colour, as to be almost black with it, may leave an impression strong enough to exhibite the desir'd colour. A pretty kinde of artificial Stuff I have seen, looking almost like transparent Parchment, Horn, or Ising-glass, and perhaps some such thing it may be made of, which being transparent, and of a glutinous nature, and easily mollified by keeping in water, as I found upon trial, had imbib d, and did remain ting'd with a great variety of very vivid colours, and to the naked eye, it look'd very like the substance of the Silk. And I have often thought, that probably there might be a way found out, to make an artificial glutinous composition, much resembling, if not full as good, nay better, then that Excrement, or whatever other substance it be out of which, the Silk-worm wire-draws his clew. If such a composition were found, it were certainly an easie matter to find very quick ways of drawing it out into small wires for use. I need not mention the use of such an Invention, nor the benefit that is likely to accrue to the finder, they being sufficiently obvious. This hint therefore, may, I hope, give some Ingenious inquisitive Person an occasion of making some trials, which if successfull, I have my aim, and I suppose he will have no occasion to be displeas'd.

Obſerv. V. *Of watered Silks, or Stuffs.*

Schem. 3. Fig. 2.

THere are but few *Artificial* things that are worth obſerving with a *Microſcope*; and therefore I ſhall ſpeak but briefly concerning them. For the Productions of art are ſuch rude miſ-ſhapen things, that when view'd with a *Microſcope*, there is little elſe obſervable, but their deformity. The moſt curious Carvings appearing no better then thoſe rude *Ruſſian* Images we find mention'd in *Purchas*, where three notches at the end of a Stick, ſtood for a face. And the moſt ſmooth and burniſh'd ſurfaces appear moſt rough and unpoliſht: So that my firſt Reaſon why I ſhall add but a few obſervations of them, is, their miſ-ſhapen form; and the next, is their uſeleſsneſs. For why ſhould we trouble our ſelves in the examination of that form or ſhape (which is all we are able to reach with a *Microſcope*) which we know was deſign'd for no higher a uſe, then what we were able to view with our naked eye? Why ſhould we endeavour to diſcover myſteries in that which has no ſuch thing in it? And like *Rabbins* find out *Caballiſms*, and *ænigmâs* in the Figure, and placing of Letters, where no ſuch thing lies hid: whereas in *natural* forms there are ſome ſo ſmall, and ſo curious, and their deſign'd buſineſs ſo far remov'd beyond the reach of our ſight, that the more we magnify the object, the more excellencies and myſteries do appear; And the more we diſcover the imperfections of our ſenſes, and the Omnipotency and Infinite perfections of the great Creatour. I ſhall therefore onely add one or two Obſervations more of *artificial* things, and then come to the Treaty concerning ſuch matters as are the Productions of a more curious Workman. One of theſe, ſhall be that of a piece of water'd Silk, repreſented in the ſecond Figure of the third *Scheme*, as it appear'd through the leaſt magnifying Glaſs. *A B.* ſignifying the long way of the Stuff, and *C D* the broad way. This Stuff, if the right ſide of it be looked upon, appears to the naked eye, all over ſo waved, undulated, or grain'd, with a curious, though irregular variety of brighter and darker parts, that it adds no ſmall gracefulneſs to the Gloſs of it. It is ſo known a propriety, that it needs but little explication, but it is obſervable, which perhaps every one has not conſidered, that thoſe parts which appear the darker part of the wave, in one poſition to the light, in another appears the lighter, and the contrary; and by this means the undulations become tranſient, and in a continual change, according as the poſition of the parts in reſpect of the incident beams of light is varied. The reaſon of which odd *phænomena*, to one that has but diligently examin'd it even with his naked eye, will be obvious enough. But he that obſerves it with a *Microſcope*, may more eaſily perceive what this *Proteus* is, and how it comes to change its ſhape. He may very eaſily perceive, that it proceeds onely from the variety of the *Reflections* of light, which is caus'd by the various *ſhape of the Particles*, or little protuberant parts of the thread that compoſe the ſurface; and that thoſe parts of the waves that

appear

appear the brighter,throw towards the eye a multitude of ſmall reflections of light, whereas the darker ſcarce afford any. The reaſon of which reflection, the *Microſcope* plainly diſcovers, as appears by the Figure. In which you may perceive, that the brighter parts of the ſurface conſiſt of an abundance of large and ſtrong reflections,denoted by *a*, *a*, *a*, *a*, *a*, &c. for the ſurfaces of thoſe threads that run the *long way*, are by the Mechanical proceſs of watering, *creas'd* or *angled* in another kind of poſture then they were by the weaving: for by the weaving they are onely ***bent round*** the warping threads; but by the watering, they are ***bent with an angle, or elbow***, that is in ſtead of lying, or being bent *round* the threads, as in the third Figure, *a*, *a*, *a*, *a*, *a*, are about *b*,*b*,*b* (*b*,*b*,*b* repreſenting the ends,as 'twere, of the croſs threads,they are bent about) they are creas'd on the top of thoſe threads, with an *angle*, as in the fourth Figure, and that with all imaginable variety; ſo that,whereas before they reflected the light onely from one point of the round ſurface, as about *c*, *c*, *c*, they now when water'd, reflect the beams from more then half the whole ſurface,as *de*, *de*, *de*, and in other poſtures they return no reflections at all from thoſe ſurfaces. Hence in one poſture they compoſe the brighter parts of the waves,in another the darker. And theſe reflections are alſo varied, according as the particular parts are variouſly bent. The reaſon of which creaſing we ſhall next examine; and here we muſt fetch our information from the Mechaniſm or manner of proceeding in this operation; which, as I have been inform'd, is no other then this.

They double all the Stuff that is to be water'd, that is,they creaſe it juſt through the middle of it, the whole length of the piece, leaving the right ſide of the Stuff inward, and placing the two edges, or ſilvages juſt upon one another,and,as near as they can,place the wale ſo in the doubling of it, that the wale of the one ſide may lie very near parallel, or even with the wale of the other; for the nearer that poſture they lie, the greater will the watering appear; and the more obliquely,or acroſs to each other they lie,the ſmaller are the waves. Their way for folding it for a great wale is thus: they take a Pin,and begin at one ſide of the piece in any wale,and ſo moving it towards the other ſide, thereby direct their hands to the oppoſite ends of the wale, and then, as near as they can, place the two oppoſite ends of the ſame wale together, and ſo double, or fold the whole piece, repeating this enquiry with a Pin at every yard or two's diſtance through the whole length; then they ſprinkle it with water,and fold it the longways, placing between every fold a piece of Paſtboard, by which means all the wrong ſide of the water'd Stuff becomes flat, and with little wales, and the wales on the other ſide become the more protuberant; whence the creaſings or angular bendings of the wales become the more perſpicuous. Having folded it in this manner,they place it with an interjacent Paſtboard into an hot Preſs, where it is kept very violently preſt, till it be dry and ſtiff; by which means, the wales of either contiguous ſides leave their own impreſſions upon each other, as is very manifeſt by the ſecond Figure, where 'tis obvious enough, that the wale of the piece *A B C D* runs parallel between the pricked lines *ef*, *ef*, *ef*, and as

manifeſt to diſcern the impreſſions upon theſe wales, left by thoſe that were preſt upon them,which lying not exactly parallel with them,but a little athwart them, as is denoted by the lines of,*o o o o*,*gh*, *gh*,*gh*, between which the other wales did lie parallel;they are ſo variouſly,and irregularly creas'd that being put into that ſhape when wet,and kept ſo till they be drie, they ſo ſet each others threads, that the Moldings remain almoſt as long as the Stuff laſts.

Hence it may appear to any one that attentively conſiders the Figure, why the parts of the wale *a*, *a*, *a*, *a*, *a*, *a*, ſhould appear bright; and why the parts *b*, *b*, *b*, *b*, *b*, *b*, ſhould appear ſhadowed, or dark; why ſome, as *d*,*d*,*d*,*d*,*d*,*d*, ſhould appear partly light,and partly dark: the varieties of which reflections and ſhadows are the only cauſe of the appearance of watering in Silks, or any other kind of Stuffs.

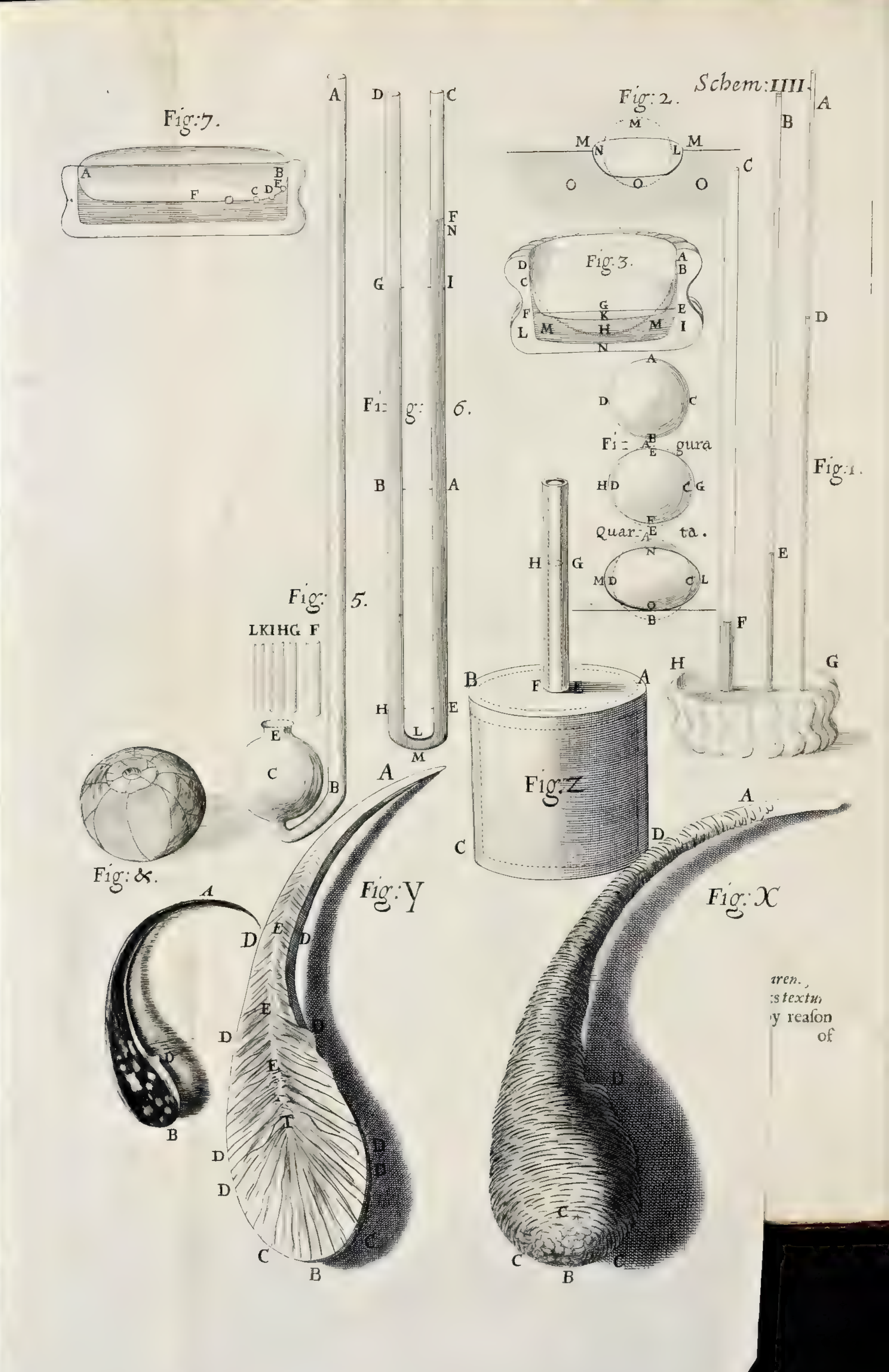
From the variety of reflection, may alſo be deduc'd the cauſe why a ſmall breez or gale of wind ruffling the ſurface of a ſmooth water, makes it appear black; as alſo,on the other ſide, why the ſmoothing or burniſhing the ſurface of whitened Silver makes it look black; and multitudes of other phænomena might hereby be ſolv'd, which are too many to be here inſiſted on.

Obſerv. VI. *Of ſmall Glaſs Canes.*

Schem. 4.

THat I might be ſatisfi'd, whether it were not poſſible to make an *Artificial* pore as *ſmall* as any *Natural* I had yet found, I made ſeveral attemps with ſmall *glaſs pipes*, melted in the flame of a Lamp, and then very *ſuddenly* drawn out into a great length. And, by *that means*, without much difficulty, I was able to draw ſome almoſt as ſmall as a *Cobweb*, which yet, with the *Microſcope*, I could plainly perceive to be *perforated*, both by looking on the *ends* of it, and by looking on it *againſt the light*; which was much the *eaſier way* to determine whether it were ſolid or perforated; for, taking a ſmall pipe of glaſs, and cloſing one end of it, then filling it *half full* of water, and holding it *againſt the light*, I could, by this means, very eaſily find what was the *differing aſpect* of a *ſolid* and a *perforated* piece of glaſs; and ſo eaſily diſtinguiſh, without ſeeing either end, whether any *Cylinder* of glaſs I look'd on, were a *ſolid ſtick*, or a *hollow cane.* And by this means,I could alſo preſently judge of any ſmall *filament* of glaſs, whether it were *hollow* or *not*, which would have been exceeding tedious to examine by looking on the end. And many ſuch like ways I was fain to make uſe of, in the examining of divers other particulars related in this Book, which would have been no eaſie task to have determined meerly by the more common way of looking on, or viewing the Object. For, if we conſider firſt, the very *faint light* wherewith the object is enlightened, whence many particles appear *opacous*, which when more enlightned, appear very *tranſparent*, ſo that I was fain to *determine* its *tranſparency* by one glaſs, and its *texture* by another Next, the *unmanageableneſs* of moſt *Objects*, by reaſon of

ser
en ther


Schem: IIII.
Fig: 7.
Fig: 2.
Fig: 3.
Fig: 6.
Figura Quarta.
Fig: 1.
Fig: 5.
Fig: Z
Fig: &.
Fig: Y
Fig: X

of their *ſmalneſs*, 3. The *difficulty of finding* the deſired point, and of *placing* it ſo, as to reflect the *light conveniently* for the Inquiry, Laſtly, ones being able to view it but with *one eye* at once, they will appear no ſmall *obſtructions*, nor are they eaſily *remov'd* without many *contrivances*. But to proceed, I could not find that water, or ſome *deeply ting'd* liquors would in ſmall ones riſe ſo high as one would expect; and the *higheſt* I have found it yet riſe in any of the pipes I have try'd, was to 21 *inches* above the level of the water in the veſſel: for though I found that in the ſmall pipes it would *nimbly enter* at firſt, and run about 6 or 7 *inches* upwards; yet I found it then to move upwards *ſo ſlow*, that I have not yet had the *patience* to obſerve it above that height of 21 *inches* (and that was in a pretty *large Pipe*, in compariſon of thoſe I formerly mentioned; for I could obſerve the *progreſs* of a *very deep ting'd liquor* in it with my *naked eye*, without much trouble; whereas many of the *other pipes* were ſo *very ſmall*, that unleſs in a *convenient poſture* to the light, I could not perceive *them* :) But 'tis very probable, that a greater *patience* and *aſſiduity* may diſcover the liquors to *riſe*, at leaſt to remain *ſuſpended*, at heights that I ſhould be loath now even to *gheſs* at, if at leaſt there be any *proportion* kept between the height of the aſcending liquor, and the *bigneſs of the holes* of the pipes.

An Attempt for the Explication of this Experiment.

My Conjecture, *That the unequal height of the ſurfaces of the water, proceeded from the greater preſſure made upon the water by the Air without the Pipes* A B C, *then by that within them*; I ſhall endeavour to confirm from the truth of the two following *Propoſitions*: *Schem. 4. Fig. 1.*

The firſt of which is, *That an unequal preſſure of the incumbent Air, will cauſe an unequal height in the water's Surfaces.*

And the ſecond is, *That in this experiment there is ſuch an unequal preſſure.*

That the firſt is true, the following *Experiment* will evince. For if you take any Veſſel ſo contrived, as that you can at pleaſure either *increaſe* or *diminiſh* the *preſſure* of the Air upon this or that part of the *Superficies* of the *water*, the *equality* of the height of thoſe parts will preſently be *loſt*; and that part of the *Superficies* that ſuſtains the *greater preſſure*, will be *inferior* to that which undergoes the *leſs*. A fit Veſſel for this purpoſe, will be an inverted Glaſs *Syphon*, ſuch an one as is deſcribed in the *Sixth Figure*. For if into it you put Water enough to fill it as high as *A B*, and gently blow in at *D*, you ſhall *depreſs* the Superficies *B*, and thereby *raiſe* the oppoſite Superficies *A* to a *conſiderable height*, and by gently *ſucking* you may produce clean *contrary* effects.

Next, That there is ſuch an *unequal preſſure*, I ſhall prove from this, *That there is a much greater incongruity of Air to Glaſs, and ſome other Bodies, then there is of Water to the ſame.*

By *Congruity, I mean a property of a fluid Body, whereby any part of it is readily united with any other part, either of it ſelf, or of any other Similar, fluid, or ſolid body: And by Incongruity a property of a fluid, by which it is hindred from uniting with any diſſimilar, fluid, or ſolid Body.*

This laſt property, any one that hath been obſervingly converſant about fluid Bodies, cannot be ignorant of. For (not now to mention ſeveral *Chymical Spirits* and *Oyls*, which will *very hardly*, if at *all*, be brought to *mix* with one another; inſomuch that there may be found ſome 8 or 9, or more, ſeveral diſtinct Liquors, which *ſwimming* one upon another, will not preſently *mix*) we need ſeek no further for Examples of this kind in *fluids*, then to obſerve the *drops of rain* falling through the *air*, and the *bubbles of air* which are by any means conveyed under the ſurface of the *water*; or a drop of common *Sallet Oyl* ſwimming upon water. In all which, and many more examples of this kind that might be enumerated, the *incongruity* of two *fluids* is eaſily diſcernable. And as for the *Congruity* or *Incongruity* of Liquids, with ſeveral kinds of *firm* Bodies, they have long ſince been taken notice of, and called by the Names of *Drineſs* and *Moiſture* (though theſe two names are not comprehenſive enough, being commonly uſed to ſignifie only the adhering or not adhering of *water* to ſome other *ſolid Bodies*) of this kind we may obſerve that *water* will more readily *wet ſome woods* then *others*; and that *water*, let fall upon a *Feather*, the whiter ſide of a *Colwort*, and ſome other leaves, or upon almoſt any *duſty*, *unctuous*, or *reſinous* ſuperficies, will not *at all adhere* to them, but eaſily *tumble off* from them, like a ſolid *Bowl*; whereas, if dropt upon *Linnen*, *Paper*, *Clay*, *green Wood*, &c. it will not be taken off, without leaving ſome part of it behind *adhering* to them. So *Quick-ſilver*, which will very *hardly* be brought to *ſtick* to any *vegetable body*, will *readily adhere* to, and *mingle* with, ſeveral clean *metalline bodies*.

And that we may the better finde what the *cauſe* of *Congruity* and *Incongruity* in bodies is, it will be requiſite to conſider, Firſt, what is the *cauſe* of *fluidneſs*; And this, *I conceive*, to be nothing elſe but a certain *pulſe* or *ſhake* of *heat*; for Heat being nothing elſe but a very *brisk* and *vehement agitation* of the parts of a body (as I have elſwhere made *probable*) the parts of a body are thereby made ſo *looſe* from one another, that they eaſily *move any way*, and become *fluid*. That I may explain this a little by a groſs Similitude, let us ſuppoſe a diſh of ſand ſet upon ſome body that is very much *agitated*, and ſhaken with ſome *quick* and *ſtrong vibrating motion*, as on a *Milſtone* turn'd round upon the under ſtone very violently whilſt it is empty; or on a very ſtiff *Drum*-head, which is vehemently or very nimbly beaten with the Drumſticks. By this means, the ſand in the diſh, which before lay like a *dull* and unactive body, becomes a perfect *fluid*; and ye can no ſooner make a *hole* in it with your finger, but it is immediately *filled up again*, and the upper ſurface of it *levell'd*. Nor can you *bury* a *light body*, as a piece of Cork under it, but it preſently *emerges* or *ſwims* as 'twere on the top; nor can you lay a *heavier* on the top of it, as a piece of Lead, but it is immediately *buried*

in

in Sand, and (as 'twere) sinks to the bottom. Nor can you make a *hole* in the side of the Dish, but the sand shall *run out* of it to a *level*, not an *obvious property* of a fluid body, as such, but this dos *imitate*; and all this meerly caused by the vehement *agitation* of the conteining vessel; for by this means, *each* sand becomes to have a *vibrative* or *dancing* motion, so as no other heavier body can *rest* on it, unless *sustein'd* by some other on either side: Nor will it suffer any Body to be *beneath* it, unless it be a *heavier* then it self. Another Instance of the strange *loosening* nature of a violent jarring Motion, or a strong and nimble vibrative one, we may have from a piece of *iron* grated on very strongly with a *file*: for if into that a pin be *screw'd* so firm and hard, that though it has a convenient head to it, yet it can by no means be *unscrew'd* by the fingers; if, I say, you attempt to unscrew this whilst *grated on by the file*, it will be found to undoe and turn very *easily*. The first of these Examples manifests, how a body actually *divided* into small parts, becomes a *fluid*. And the latter manifests by what means the agitation of heat so easily *loosens* and *unties* the parts of *solid* and *firm* bodies. Nor need we suppose heat to be any thing else, besides such a motion; for supposing we could *Mechanically* produce such a one *quick* and *strong* enough, we need not spend *fuel* to *melt* a body. Now, that I do not speak this altogether groundless, I must refer the Reader to the Observations I have made upon the shining sparks of Steel, for there he shall find that *the same* effects are produced upon small chips or parcels of Steel by the *flame*, and by *a quick and violent motion*; and if the body of *steel* may be thus melted (as I there shew it may) I think we have little reason to doubt that almost *any other* may not also. Every Smith can inform one how quickly both his *File* and the *Iron* grows *hot* with *filing*, and if you *rub* almost any two *hard* bodies together, they will do the same: And we know, that a sufficient degree of heat causes *fluidity*, in some bodies much sooner, and in others later; that is, the parts of the body of some are so *loose* from one another, and so *unapt to cohere*, and so *minute* and *little*, that a very *small* degree of agitation keeps them always in the *state of fluidity*. Of this kind, I suppose, the *Æther*, that is the *medium* or *fluid* body, in which all other bodies do as it were swim and move; and particularly, the *Air*, which seems nothing else but a kind of *tincture* or *solution* of terrestrial and aqueous particles *dissolv'd* into it, and agitated by it, just as the *tincture* of *Cocheneel* is nothing but some finer *dissoluble* parts of that Concrete lick'd up or *dissolv'd* by the *fluid* water. And from this Notion of it, we may easily give a more Intelligible reason how the Air becomes so capable of *Rarefaction* and *Condensation*. For, as in *tinctures*, one grain of some *strongly tinging* substance may *sensibly* colour some *hundred thousand* grains of *appropriated* Liquors, so as every *drop* of it has its proportionate share, and be sensibly ting'd, as I have try'd both with *Logwood* and *Cocheneel*: And as some few grains of *Salt* is able to infect as great a quantity, as may be found by *præcipitations*, though not so easily by the *sight* or *taste*; so the *Air*, which seems to be but as 'twere a *tincture* or *saline substance, dissolv'd and agitated by the fluid and agil Æther*, may disperse

perſe and *expand* it ſelf into a *vaſt ſpace*, if it have room enough, and infect,as it were,every part of that ſpace. But,as on the other ſide,if there be but ſome *few grains* of the liquor, it may *extract all* the colour of the tinging ſubſtance, and may *diſſolve* all the Salt, and thereby become *much more impregnated* with thoſe ſubſtances, ſo may *all* the air that ſufficed in a *rarify'd ſtate* to fill ſome *hundred thouſand* ſpaces of Æther, be compris'd in only *one*,but in a poſition proportionable *denſe*. And though we have not yet found out ſuch *ſtrainers* for Tinctures and Salts as we have for the Air, being yet unable to *ſeparate* them from their diſſolving liquors by any kind of *filtre*, without *præcipitation*, as we are able to *ſeparate* the Air from the Æther by *Glaſs*, and ſeveral other bodies. And though we are yet unable and ignorant of the ways of *præcipitating* Air out of the Æther as we can Tinctures, and Salts out of ſeveral *diſſolvents*; yet neither of theſe ſeeming *impoſſible* from the nature of the things, nor ſo *improbable* but that ſome happy future induſtry may find out ways to effect them; nay, further, ſince we find that Nature *does really perform* (though by what means we are not certain) both theſe actions, namely, by *præcipitating* the Air in Rain and Dews, and by ſupplying the Streams and Rivers of the World with freſh water, *ſtrain'd* through ſecret ſubterraneous Caverns: And ſince, that in very many other *proprieties* they do ſo exactly *ſeem* of the *ſame nature*; till further obſervations or tryals do inform us of the *contrary*, we may *ſafely enough conclude* them of the *ſame kind*. For it ſeldom happens that any two natures have ſo many properties *coincident* or the *ſame*, as I have obſerv'd Solutions and Air to have, and to be *different* in the reſt. And therefore I think it neither *impoſſible*, *irrational*, nay nor *difficult* to be able to *predict* what is *likely* to happen in other particulars alſo, beſides thoſe which *Obſervation* or *Experiment* have declared thus or thus; eſpecially, if the *circumſtances* that do often very much conduce to the variation of the effects be duly *weigh'd* and *conſider'd*. And indeed, were there not a *probability* of this, our *inquiries* would be *endleſs*, our *tryals vain*, and our greateſt *inventions* would be nothing but the meer *products* of *chance*, and not of *Reaſon*; and, like *Mariners* in an Ocean, deſtitute both of a *Compaſs* and the ſight of the *Celeſtial guids*, we might indeed, *by chance*, Steer *directly* towards our deſired Port, but 'tis *a thouſand to one* but we *miſs* our aim. But to proceed, we may hence alſo give a plain reaſon, how the Air comes to be *darkned* by *clouds*, &c. which are nothing but a kind of *precipitation*, and how thoſe *precipitations* fall down in *Showrs*. Hence alſo could I very eaſily, and I think truly, deduce the cauſe of the curious *ſixangular figures* of Snow, and the appearances of *Haloes*, *&c.* and the ſudden *thickning* of the Sky with Clouds, and the *vaniſhing* and *diſappearing* of thoſe Clouds again; for all theſe things may be very eaſily *imitated* in a *glaſs of liquor*,with ſome ſlight *Chymical preparations* as I have often try'd, and may ſomewhere elſe more largely relate, but have not now time to ſet them down. But to proceed, there are other bodies that conſiſt of particles more *Groſs*, and of a more *apt* figure for *coheſion*, and this requires a *ſomewhat greater* agitation; ſuch, I ſuppoſe ☿. *fermented vinous*

Spirits

Spirits, ſeveral *Chymical Oils*, which are much of kin to thoſe Spirits, &c. Others yet require a *greater*, as *water*, and ſo others *much greater*, for almoſt infinite degrees: For, I ſuppoſe there are very *few* bodies in the world that may not be made *aliquatenus* fluid, by *ſome* or *other* degree of agitation or heat.

Having therefore in ſhort ſet down my Notion of a Fluid body, I come in the next place to conſider what *Congruity* is; and this, as I ſaid before, being a *Relative property* of a fluid, whereby it may be ſaid to be *like* or *unlike* to this or that other body, whereby it *does* or *does not mix* with this or that body. We will again have recourſe to our former Experiment, though but a rude one; and here if we mix in the diſh *ſeveral kinds* of ſands, ſome of *bigger*, others of *leſs* and finer bulks, we ſhall find that by the agitation the *fine ſand* will *eject* and *throw out* of it ſelf all thoſe *bigger* bulks of ſmall *ſtones* and the like, and thoſe will be *gathered* together all into *one* place; and if there be *other* bodies in it of other natures, thoſe alſo will be *ſeparated* into a place by themſelves, and *united* or *tumbled* up together. And though this do not come up to the *higheſt property* of *Congruity*, which is a *Cohæſion* of the parts of the fluid together, or a kind of *attraction* and *tenacity*, yet this does as 'twere *ſhadow* it out, and ſomewhat reſemble it; for juſt after the ſame manner, I ſuppoſe the *pulſe* of heat to *agitate* the ſmall parcels of matter, and thoſe that are of a *like bigneſs*, and *figure*, and *matter*, will *hold*, or *dance* together, and thoſe which are of a *differing* kind will be *thruſt* or *ſhov'd* out from between them; for particles that are all *ſimilar*, will, like ſo many *equal muſical ſtrings equally ſtretcht*, vibrate together in a kind of *Harmony* or *uniſon*; whereas others that are *diſſimilar*, upon what account ſoever, unleſs the diſproportion be otherwiſe counter-ballanc'd, will, like ſo many *ſtrings out of tune* to thoſe uniſons, though they have the ſame agitating *pulſe*, yet make quite *differing* kinds of *vibrations* and *repercuſſions*, ſo that though they may be both mov'd, yet are their *vibrations* ſo *different*, and ſo *untun'd*, as 'twere to each other, that they *croſs* and *jar* againſt each other, and conſequently, *cannot agree* together, but *fly back* from each other to their ſimilar particles. Now, to give you an inſtance how the *diſproportion* of ſome bodies in one reſpect, may be *counter-ballanc'd* by a *contrary diſproportion* of the ſame body in another reſpect, whence we find that the ſubtil *vinous ſpirit* is *congruous*, or does readily *mix* with *water*, which in many properties is of a very *differing nature*, we may conſider that a *uniſon* may be made either by two *ſtrings* of the ſame *bigneſs*, *length*, and *tenſion*, or by two ſtrings of the ſame *bigneſs*, but of *differing length*, and a *contrary differing tenſion*; or 3*ly*. by two ſtrings of *unequal length* and *bigneſs*, and of a *differing tenſion*, or of *equal length*, and *differing bigneſs* and *tenſion*, and ſeveral other ſuch varieties. To which *three properties* in *ſtrings*, will correſpond *three proprieties* alſo in *ſand*, or the *particles* of bodies, their *Matter* or *Subſtance*, their *Figure* or *Shape*, and their *Body* or *Bulk*. And from the *varieties* of theſe *three*, may ariſe *infinite varieties* in fluid bodies, though all agitated by the *ſame pulſe* or *vibrative* motion. And there may be as many ways of making Harmonies

and

and Discords with these, as there may be with *musical strings*. Having therefore seen what is the cause of Congruity or Incongruity, those relative properties of fluids, we may, from what has been said, very easily collect, what is the *reason* of those Relative proprieties also between *fluid bodies* and *solid*; for since all bodies consist of *particles* of such a *Substance*, *Figure*, and *Bulk*; but in some they are *united* together more *firmly* then to be *loosened* from each other by every *vibrative* motion (though I imagine that there is no body in the world, but that some degree of agitation may, as I hinted before, agitate and loosen the particles so as to make them fluid) those *cohering* particles may *vibrate* in the same manner almost as those that are *loose* and become *unisons* or *discords*, as I may so speak, to them. Now that the *parts* of all *bodies*, though never so *solid*, do yet *vibrate*, I think we need go no furthe for proof, then that *all* bodies have some *degrees* of *heat* in them, and that there has not been yet found any thing *perfectly cold*: Nor can I believe indeed that there is any such thing in Nature, as a body whose particles are at *rest*, or *lazy* and *unactive* in the great *Theatre* of the *World*, it being quite *contrary* to the grand *Oeconomy* of the Universe. We see therefore what is the reason of the *sympathy* or uniting of some bodies together, and of the *antipathy* or flight of others from each other: For *Congruity* seems nothing else but a *Sympathy*, and *Incongruity* an *Antipathy* of bodies; hence *similar* bodies once *united* will not *easily part*, and *dissimilar* bodies once *disjoyn'd* will not *easily unite* again; from hence may be very easily deduc'd the reason of the *suspension* of *water* and *Quick-silver* above their usual *station*, as I shall more at large anon shew.

These properties therefore (alwayes the concomitants of fluid bodies) produce these following visible *Effects*:

First, They *unite* the parts of a fluid to its *similar* Solid, or keep them *separate* from its *dissimilar*. Hence *Quick-silver* will (as we noted before) *stick* to *Gold*, *Silver*, *Tin*, *Lead*, &c. and *unite* with them: but *roul* off from *Wood*, *Stone*, *Glass*, &c. if never so little scituated out of its *horizontal level*; and *water* that will *wet salt* and *dissolve* it, will *slip* off from *Tallow*, or the like, without at all *adhering*; as it may likewise be observed to do upon a *dusty* superficies. And next they cause the parts of *homogeneal fluid* bodies readily to *adhere* together and *mix*, and of *heterogeneal*, to be exceeding *averse* thereunto. Hence we find, that *two* small *drops* of *water*, on any superficies they can roul on, will, if they chance to touch each other, *readily unite* and *mix* into one 3[d] *drop*: The like may be observed with two small *Bowls* of *Quick-silver* upon a Table or Glass, provided their surfaces be not *dusty*; and with two drops of *Oyl* upon fair water, *&c.* And further, *water* put unto *wine*, *salt water*, *vinegar*, *spirit* of *wine*, or the like, does immediately (especially if they be shaken together) *disperse* it self all over them. Hence, on the contrary, we also find, that *Oyl of Tartar* poured upon *Quick-silver*, and *Spirit of Wine* on that *Oyl*, and *Oyl of Turpentine* on that *Spirit*, and *Air* upon that *Oyl*, though they be stopt closely up into a Bottle, and *shaken* never so much, they will by no means long suffer any of their bigger parts to be *united* or included

cluded within any of the other Liquors(by which recited Liquors,may be plainly enough represented the four *Peripatetical Elements*, and the more subtil *Æther* above all.) From this property'tis, that a drop of *water* does not mingle with, or vanish into *Air*, but is *driven* (by that Fluid equally protruding it on every side) and forc't into as little a space as it can possibly be contained in, namely, into a *Round Globule*. So likewise a little *Air* blown under the *water*, is *united* or thrust into a *Bubble* by the ambient water. And a parcel of *Quick-silver* enclosed with *Air*, *Water*, or almost any other *Liquor*, is *formed* into a *round Ball*.

Now the cause why all these included Fluids, newly mentioned, or as many others as are wholly included within a heterogeneous fluid, are not *exactly* of a *Spherical Figure* (seeing that if caused by these Principles only, it could be of no other) must proceed from some other kind of *pressure* against the two opposite flatted sides. This *adventitious* or *accidental pressure* may proceed from *divers causes*, and accordingly must *diversifie* the Figure of the included heterogeneous fluid: For seeing that a body may be included either with a fluid only, or only with a solid, or partly with a fluid, and partly with a solid, or partly with one fluid, and partly with another; there will be found a very great variety of the terminating *surfaces*, much differing from a *Spherical*, according to the various resistance or pressure that belongs to each of these encompassing bodies.

Which Properties may in general be deduced from two heads, *viz.* *Motion*, and *Rest*. For, either this Globular Figure is altered by a *natural Motion*, such as is *Gravity*; or a *violent*, such as is any *accidental motion* of the fluids, as we see in the *wind* ruffling up the water,and the *purlings* of *Streams*, and *foaming* of *Catarracts*, and the like. Or thirdly, By the *Rest*, *Firmness* and *Stability* of the ambient *Solid*. For if the including *Solid* be of an *angular* or any other *irregular* Form, the included *fluid* will be near of the *like*,as a Pint-*Pot* full of *water*,or a *Bladder* full of *Air*. And next, if the including or included fluid have a greater *gravity* one than another,then will the *globular* Form be deprest into an *Elliptico-spherical*: As if, for example, we suppose the Circle *A B C D*, in the *fourth Figure*, to represent a *drop of water*, *Quick-silver*, or the like, included with the *Air* or the like, which supposing there were no *gravity* at all in either of the *fluids*, or that the *contained* and *containing* were of the *same weight*, would be *equally comprest* into an exactly *spherical* body (the ambient fluid *forcing equally* against every side of it.) But supposing either a greater *gravity* in the included, by reason whereof the parts of it being *prest* from *A* towards *B*, and thereby the whole put into *motion*, and that *motion* being *hindred* by the *resistance* of the *subjacent* parts of the ambient, the *globular* Figure *A D B C* will be *deprest* into the *Elliptico-spherical*, *E G F H*. For the side *A* is *detruded* to *E* by the *Gravity*, and *B* to *F* by the *resistance* of the subjacent medium: and therefore *C* must necessarily be thrust to *G*; and *D* to *H*. Or else, supposing a greater *gravity* in the *ambient*, by whose more then ordinary *pressure* against the under side of the included globule; *B* will be forced to *F*, and by its *resistance* of

the motion *upwards*, the ſide *A* will be *depreſt* to *E*, and therefore *C* being thruſt to *G* and *D* to *H*; the *globular* Figure by this means alſo will be made an *Elliptico-ſpherical.* Next if a fluid be included *partly* with one, and *partly* with another fluid, it will be found to be ſhaped *diverſly*, according to the proportion of the *gravity* and *incongruity* of the 3 *fluids* one to another: As in the *ſecond Figure*, let the upper *M M M* be *Air*, the middle *L M N O* be common *Oyl*, the lower *O O O* be *Water*, the *Oyl* will be form'd, not into a *ſpherical* Figure, ſuch as is repreſented by the *pricked Line*, but into ſuch a Figure as L M N O, whoſe ſide L M N will be of a flatter *Elliptical* Figure, by reaſon of the great diſproportion between the *Gravity* of *Oyl* and *Air*, and the ſide L O M of a rounder, becauſe of the ſmaller difference between the weight of *Oyl* and *Water.* Laſtly, The *globular* Figure will be changed, if the *ambient* be partly *fluid* and partly *ſolid.* And here the termination of the incompaſſed *fluid* towards the incompaſſing is ſhap'd according to the proportion of the congruity or incongruity of the *fluids* to the *ſolids*, and of the gravity and incongruity of the *fluids* one to another. As ſuppoſe the ſubjacent *medium* that hinders an included fluids deſcent, be a *ſolid*, as let K I, in the *fourth Figure*, repreſent the ſmooth ſuperficies of a *Table*; E G F H, a parcel of *running Mercury*; the ſide G F H will be more flatted, according to the proportion of the incongruity of the *Mercury* and *Air* to the *Wood*, and of the *gravity* of *Mercury* and *Air* one to another; The ſide G E H will likewiſe be a little more depreſt by reaſon the ſubjacent parts are now at reſt, which were before in motion.

Or further in the *third Figure*, let A I L D repreſent an including *ſolid* medium of a cylindrical ſhape (as ſuppoſe a ſmall *Glaſs Jar*) Let F G E M M repreſent a contain'd *fluid*, as water; this towards the bottom and ſides, is figured according to the concavity of the *Glaſs*: But its upper *Surface*, (which by reaſon of its gravity, (not conſidering at all the Air above it, and ſo neither the congruity or incongruity of either of them to the Glaſs) ſhould be terminated by part of a *Sphere* whoſe diameter ſhould be the ſame with that of the earth, which to our ſenſe would appear a ſtraight *Line*, as F G E, Or which by reaſon of its having a greater congruity to Glaſs than Air has, (not conſidering its Gravity) would be thruſt into a *concave Sphere*, as C H B, whoſe diameter would be the ſame with that of the concavity of the Veſſel:) Its upper Surface, I ſay, by reaſon of its having a greater gravity then the Air, and having likewiſe a greater congruity to Glaſs then the Air has, is terminated, by a *concave Elliptico-ſpherical* Figure, as C K B. For by its congruity it eaſily conforms it ſelf, and adheres to the Glaſs, and conſtitutes as it were one containing body with it, and therefore ſhould thruſt the contained Air on that ſide it touches it, into a *ſpherical* Figure, as B H C, but the motion of Gravity depreſſing a little the Corners B and C, reduces it into the aforeſaid Figure C K B. Now that it is the greater congruity of one of the two *contiguous fluids*, then of the other, to the containing *ſolid*, that cauſes the ſeparating ſurfaces to be thus or thus figured: And that it is not becauſe this or that figurated ſurface is more proper, natural, or peculiar to

one

one of these fluid bodies, then to the other, will appear from this; that the same *fluids* will by being put into differing *solids*, change their *surfaces*. For the same water, which in a Glass or wooden Vessel will have a concave surface upwards, and will rise higher in a smaller then a greater Pipe, the same water, I say, in the same Pipes greased over or oyled, will produce quite contrary effects; for it will have a *protuberant* and *convex* surface upwards, and will not rise so high in small, as in bigger Pipes: Nay, in the very same solid Vessel, you may make the very same two contiguous *Liquids* to alter their Surfaces; for taking a small Wine-glass, or such like Vessel, and pouring water gently into it, you shall perceive the *surface* of the water all the way *concave*, till it rise even with the top, when you shall find it (if you gently and carefully pour in more) to grow very *protuberant* and *convex*; the reason of which is plain, for that the *solid* sides of the containing body are no longer extended, to which the water does more readily adhere then the air; but it is henceforth to be included with air, which would reduce it into a *hemisphere*, but by reason of its *gravity*, it is flatted into an *Oval*. *Quicksilver* also which to *Glass* is more incongruous then *Air* (and thereby being put into a *Glass-pipe*, will not adhere to it, but by the more *congruous air* will be forced to have a very *protuberant* surface, and to rise higher in a greater then a lesser Pipe) this *Quicksilver* to clean *Metal*, especially to *Gold*, *Silver*, *Tin*, *Lead*, &c. *Iron* excepted, is more *congruous* then *Air*, and will not only stick to it, but have a *concave* Surface like *water*, and rise higher in a less, then in a greater Pipe.

In all these Examples it is evident, that there is an *extraordinary* and *adventitious force*, by which the *globular* Figure of the contained *heterogeneous* fluid is altered; neither can it be imagined, how it should otherwise be of any other Figure then *Globular*: For being by the *heterogeneous* fluid equally *protruded* every way, whatsoever part is *protuberant*, will be thereby *deprest*. From this cause it is, that in its effects it does very much resemble a *round Spring* (such as a *Hoop*.) For as in a *round Spring* there is required an additional *pressure* against two opposite sides, to reduce it into an *Oval* Form, or to force it in between the sides of a *Hole*, whose *Diameter* is less then that of the *Spring*, there must be a considerable force or *protrusion* against the *concave* or inner side of the *Spring*; So to alter this *spherical* constitution of an included fluid body, there is required more pressure against opposite sides to reduce it into an *Oval*; and, to press it into an *Hole* less in *Diameter* then it self, it requires a greater *protrusion* against all the other sides. What degrees of force are requisite to reduce them into longer and longer *Ovals*, or to press them into less and less *holes*, I have not yet experimentally calculated; but thus much by experiment I find in general, that there is alwayes required a greater pressure to close them into longer *Ovals*, or protude them into smaller *holes*. The necessity and reason of this, were it requisite, I could easily explain: but being not so necessary, and requiring more room and time then I have for it at present, I shall here omit it; and proceed to shew, that this may be presently found true, if Experiment be made with a

round Spring (the way of making which trials is *obvious* enough.) And with the fluid bodies of *Mercury*, *Air*, *&c*, the way of trying which, will be ſomewhat more difficult ; and therefore I ſhall in brief deſcribe it. He therefore that would try with *Air*, muſt firſt be provided of a *Glaſs-pipe*, made of the ſhape of that in the *fifth Figure*, whereof the ſide A B, repreſents a ſtraight *Tube* of about three foot long, C, repreſents another part of it, which conſiſts of a *round Bubble* ; ſo ordered, that there is left a *paſſage* or *hole* at the top, into which may be faſtened with *cement* ſeveral *ſmall Pipes* of determinate *cylindrical* cavities : as let the *hollow* of

F. G. H. I. K. L. M. *&c*	be	$\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{12}$, $\frac{1}{16}$, $\frac{1}{24}$, $\frac{1}{32}$	of an inch.

There may be added as many more, as the Experimenter ſhall think fit, with holes continually decreaſing by known quantities, ſo far as his ſenſes are able to help him ; I ſay, ſo far, becauſe there may be made *Pipes* ſo ſmall that it will be impoſſible to perceive the *perforation* with ones naked eye, though by the help of a *Microſcope*, it may eaſily enough be perceived : Nay, I have made a *Pipe* perforated from end to end, ſo ſmall, that with my naked eye I could very hardly ſee the body of it, inſomuch that I have been able to knit it up into a knot without breaking : And more accurately examining one with my *Microſcope*, I found it not ſo big as a ſixteenth part of one of the ſmaller hairs of my head which was of the ſmaller and finer ſort of hair, ſo that ſixteen of theſe *Pipes* bound faggot-wiſe together, would but have equalized one ſingle hair ; how ſmall therefore muſt its *perforation* be ? It appearing to me through the *Microſcope* to be a proportionably *thick-ſided Pipe*.

To proceed then, for the trial of the Experiment, the Experimenter muſt place the *Tube* A B, perpendicular, and fill the *Pipe* F (cemented into the hole E) with water, but leave the *bubble* C full of *Air*, and then gently pouring in water into the Pipe A B, he muſt obſerve diligently how high the water will riſe in it before it protrude the *bubble* of Air C, through the narrow paſſage of F, and denote exactly the height of the *Cylinder* of water, then cementing in a ſecond Pipe as G, and filling it with water ; he may proceed as with the former, denoting likewiſe the height of the *Cylinder* of water, able to protrude the *bubble* C through the paſſage of G, the like may he do with the next *Pipe*, and the next, *&c.* as far as he is able : then comparing the ſeveral heights of the *Cylinders*, with the ſeveral *holes* through which each *Cylinder* did force the *air* (having due regard to the *Cylinders* of water in the ſmall *Tubes*) it will be very eaſie to determine, what force is requiſite to preſs the *Air* into ſuch and ſuch *a hole*, or (to apply it to our preſent experiment) how

how much of the preſſure of the *Air* is taken off by its ingreſs into ſmaller and ſmaller *holes*. From the application of which to the entring of the *Air* into the bigger *hole* of the *Veſſel*, and into the ſmaller *hole* of the *Pipe*, we ſhall clearly find, that there is a greater preſſure of the air upon the water in the *Veſſel* or greater *pipe*, then there is upon that in the leſſer *pipe*: For ſince the preſſure of the *air* every way is found to be equal, that is, as much as is able to preſs up and ſuſtain a *Cylinder* of *Quickſilver* of two foot and a half high, or thereabouts; And ſince of this preſſure ſo many more degrees are required to force the *Air* into a ſmaller then into a greater *hole* that is full of a more congruous fluid. And laſtly, ſince thoſe degrees that are requiſite to preſs it in, are thereby taken off from the *Air* within, and the *Air* within left with ſo many degrees of preſſure leſs then the *Air* without; it will follow, that the *Air* in the leſs *Tube* or *pipe*, will have leſs preſſure againſt the ſuperficies of the *water* therein, then the *Air* in the bigger: which was the minor Propoſition to be proved.

The Concluſion therefore will neceſſarily follow, *viz.* That *this unequal preſſure of the Air cauſed by its ingreſs into unequal holes, is a cauſe ſufficient to produce this effect, without the help of any other concurrent*; and therefore is probably the principal (if not the only) cauſe of theſe *Phænomena.*

This therefore being thus explained, there will be divers *Phænomena* explicable thereby, as, the riſing of *Liquors* in a *Filtre*, the riſing of *Spirit of Wine, Oyl, melted Tallow, &c.* in the *Week* of a *Lamp*, (though made of ſmall *Wire, Threeds* of *Asbeſtus, Strings* of *Glaſs*, or the like) the riſing of *Liquors* in a *Spunge*, piece of *Bread, Sand, &c.* perhaps alſo the aſcending of the *Sap* in *Trees* and *Plants*, through their ſmall, and ſome of them *imperceptible pores*, (of which I have ſaid more, on another occaſion) at leaſt the paſſing of it out of the earth into their roots. And indeed upon the conſideration of this Principle, multitudes of other uſes of it occurr'd to me, which I have not yet ſo well examined and digeſted as to propound for *Axioms*, but only as *Queries* and *Conjectures* which may ſerve as *hints* toward ſome further *diſcoveries.*

As firſt, Upon the conſideration of the *congruity* and *incongruity* of Bodies, as to *touch*, I found alſo the like *congruity* and *incongruity* (if I may ſo ſpeak) as to the *Tranſmitting* of the *Raies* of Light: For as in this regard, *water* (not now to mention other Liquors) ſeems nearer of affinity to *Glaſs* then *Air*, and *Air* then *Quickſilver* : whence an *oblique Ray* out of *Glaſs*, will paſs into *water* with very little *refraction* from the *perpendicular*, but none out of *Glaſs* into *Air*, excepting a *direct*, will paſs without a very great refraction from the perpendicular, nay any oblique Ray under thirty degrees, will not be admitted into the Air at all. And *Quickſilver* will neither admit oblique or direct, but reflects all; ſeeming, as to the tranſmitting of the Raies of Light, to be of a quite differing conſtitution, from that of *Air, Water, Glaſs, &c.* and to reſemble moſt thoſe opacous and ſtrong reflecting bodies of Metals: So alſo as to the property of coheſion or congruity, Water ſeems to keep the ſame order, being

more

more congruous to Glaſs then Air, and Air then Quickſilver.

A Second thing (which was hinted to me, by the conſideration of the included fluids globular form, cauſed by the protruſion of the ambient heterogeneous fluid) was, whether the *Phænomena* of gravity might not by this means be explained, by ſuppoſing the *Globe* of Earth, Water, and Air to be included with a *fluid*, heterogeneous to all and each of them, ſo ſubtil, as not only to be every where *interſperſed* through the *Air*, (or rather the *air* through it) but to *pervade* the bodies of *Glaſs*, and even the *cloſeſt Metals*, by which means it may endeavour to *detrude* all earthly bodies as far from it as it can; and partly thereby, and partly by other of its properties may move them towards the Center of the Earth. Now that there is ſome ſuch fluid, I could produce many Experiments and Reaſons, that do ſeem to prove it: But becauſe it would ask ſome time and room to ſet them down and explain them, and to conſider and anſwer all the Objections (many whereof I foreſee) that may be alledged againſt it; I ſhall at preſent proceed to other *Queries*, contenting my ſelf to have here only given a hint of what I may ſay more elſwhere.

A Third *Query* then was, Whether the *heterogeneity* of the *ambient fluid* may not be accounted a *ſecondary cauſe* of the *roundneſs* or *globular form* of the *greater bodies* of the world, ſuch as are thoſe of the *Sun*, *Stars*, and *Planets*, the *ſubſtance* of each of which ſeems altogether *heterogeneous* to the *circum-ambient fluid æther*? And of this I ſhall ſay more in the Obſervation of the Moon.

A Fourth was, Whether the *globular form* of the *ſmaller parcels* of matter here upon the *Earth*, as that of *Fruits*, *Pebbles*, or *Flints*, *&c.* (which ſeem to have been a *Liquor* at firſt) may not be cauſed by the *heterogeneous ambient fluid*. For thus we ſee that melted *Glaſs* will be naturally formed into a *round Figure*; ſo likewiſe any ſmall Parcel of any *fuſible body*, if it be perfectly encloſed by the *Air*, will be driven into a *globular* Form; and, when cold, will be found a *ſolid Ball*. This is plainly enough manifeſted to us by their way of making *ſhot* with the *drops of Lead*; which being a very pretty curioſity, and known but to a very few, and having the liberty of publiſhing it granted me, by that *Eminent Virtuoſo* Sir *Robert Moray*, who brought in this Account of it to the *Royal Society*, I have here tranſcribed and inſerted.

To make ſmall ſhot of different ſizes; Communicated by his Highneſs *P. R.*

Take Lead out of the Pig what quantity you pleaſe, melt it down, ſtir and clear it with an iron Ladle, gathering together the blackiſh parts that ſwim at top like ſcum, and when you ſee the colour of the clear Lead to be greeniſh, but no ſooner, ſtrew upon it Auri-

pigmentum

pigmentum *powdered according to the quantity of Lead, about as much as will lye upon a half Crown piece will ſerve for eighteen or twenty pound weight of ſome ſorts of Lead; others will require more, or leß. After the* Auripigmentum *is put in, ſtir the Lead well, and the* Auripigmentum *will flame: when the flame is over, take out ſome of the Lead in a Ladle having a lip or notch in the brim for convenient pouring out of the Lead,and being well warmed amongſt the melted Lead, and with a ſtick make ſome ſingle drops of Lead trickle out of the Ladle into water in a Glaſs, which if they fall to be round and without tails, there is* Auripigmentum *enough put in, and the temper of the heat is right, otherwiſe put in more. Then lay two bars of Iron (or ſome more proper Iron-tool made on purpoſe) upon a Pail of water,and place upon them a round Plate of Copper, of the ſize and figure of an ordinary large Pewter or Silver Trencher, the hollow whereof is to be about three inches over, the bottom lower then the brims about half an inch, pierced with thirty, forty, or more ſmall holes; the ſmaller the holes are, the ſmaller the ſhot will be; and the brim is to be thicker then the bottom,to conſerve the heat the better.*

The bottom of the Trencher being ſome four inches diſtant from the water in the Pail,lay upon it ſome burning Coles,to keep the Lead melted upon it. Then with the hot Ladle take Lead off the Pot where it ſtands melted, and pour it ſoftly upon the burning Coles over the bottom of the Trencher, and it will immediately run through the holes into the water in ſmall round drops. Thus pour on new Lead ſtill as faſt as it runs through the Trencher till all be done; blowing now and then the Coles with hand-Bellows, when the Lead in the Trencher cools ſo as to ſtop from running.

Whilſt one pours on the Lead, another muſt, with another Ladle, thruſted four or five inches under water in the Pail, catch from time to time ſome of the ſhot,as it drops down, to ſee the ſize of it, and whether there be any faults in it. The greateſt care is to keep the Lead upon the Trencher in the right degree of heat; if it be too cool, it will not run through the Trencher, though it ſtand melted upon it; and this is to

be

be helped by blowing the Coals a little, or pouring on new Lead that is hotter: but the cooler the Lead, the larger the Shot; and the hotter, the ſmaller; when it is too hot, the drops will crack and fly; then you muſt ſtop pouring on new Lead, and let it cool; and ſo long as you obſerve the right temper of the heat, the Lead will conſtantly drop into very round Shot, without ſo much as one with a tail in many pounds.

When all is done, take your Shot out of the Pail of water, and put it in a Frying-pan over the fire to dry them, which muſt be done warily, ſtill ſhaking them that they melt not; and when they are dry you may ſeparate the ſmall from the great, in Pearl Sives made of Copper or Lattin let into one another, into as many ſizes as you pleaſe. But if you would have your Shot larger then the Trencher makes them, you may do it with a Stick, making them trickle out of the Ladle, as hath been ſaid.

If the Trencher be but toucht a very little when the Lead ſtops from going through it, and be not too cool, it will drop again, but it is better not to touch it at all. At the melting of the Lead take care that there be no kind of Oyl, Greaſe, or the like, upon the Pots, or Ladles, or Trencher.

The Chief cauſe of this Globular Figure of the Shot, ſeems to be the Auripigmentum; *for, as ſoon as it is put in among the melted Lead, it loſes its ſhining brightneſs, contracting inſtantly a grayiſh film or skin upon it, when you ſcum it to make it clean with the Ladle. So that when the Air comes at the falling drop of the melted Lead, that skin conſtricts them every where equally: but upon what account, and whether this be the true cauſe, is left to further diſquiſition,*

Much after this ſame manner, when the Air is exceeding cold through which it paſſes, do we find the drops of Rain, falling from the Clouds, congealed into round Hail-ſtones by the freezing Ambient.

To which may be added this other known Experiment, That if you gently let fall a drop of *water* upon ſmall *ſand* or *duſt*, you ſhall find, as it were, an artificial *round ſtone* quickly generated. I cannot upon this occaſion omit the mentioning of the ſtrange kind of *Grain*, which I have obſerved in a *ſtone* brought from *Kettering* in *Northamptonſhire*, and therefore called by Maſons *Kettering-Stone*; of which ſee the Deſcription.

Which

Which brings into my mind what I long ſince obſerved in the fiery Sparks that are ſtruck out of a Steel. For having a great deſire to ſee what was left behind, after the Spark was gone out, I purpoſely ſtruck fire over a very white piece of Paper, and obſerving diligently where ſome conſpicuous ſparks went out, I found a very little black ſpot no bigger then the point of a Pin, which through a *Microſcope* appeared to be a perfectly round Ball, looking much like a poliſht ball of Steel, inſomuch that I was able to ſee the Image of the window reflected from it. I cannot here ſtay (having done it more fully in another place) to examine the particular Reaſons of it, but ſhall only hint, that I imagine it to be ſome ſmall parcel of the Steel, which by the violence of the motion of the ſtroke (moſt of which ſeems to be impreſt upon thoſe ſmall parcels) is made ſo glowing hot, that it is melted into a *Vitrum*, which by the ambient Air is thruſt into the form of a Ball.

A Fifth thing which I thought worth Examination was, Whether the motion of all kind of Springs, might not be reduced to the Principle whereby the included *heterogeneous fluid* ſeems to be moved; or to that whereby two Solids, as Marbles, or the like, are thruſt and kept together by the *ambient fluid*.

A Sixth thing was, Whether the Riſing and Ebullition of the Water out of Springs and Fountains (which lie much higher from the Center of the Earth then the Superficies of the Sea, from whence it ſeems to be derived) may not be explicated by the riſing of Water in a ſmaller Pipe: For the Sea-water being ſtrained through the Pores or Crannies of the Earth, is, as it were, included in little Pipes, where the preſſure of the Air has not ſo great a power to reſiſt its riſing: But examining this way, and finding in it ſeveral difficulties almoſt irremovable, I thought upon a way that would much more naturally and conceivably explain it, which was by this following Experiment: I took a Glaſs-Tube, of the form of that deſcribed in the ſixth Figure, and chuſing two *heterogeneous fluids*, ſuch as Water and Oyl, I poured in as much Water as filled up the Pipes as high as A B, then putting in ſome Oyl into the Tube A C, I depreſt the ſuperficies A of the Water to E, and B I raiſed to G, which was not ſo high perpendicularly as the ſuperficies of the Oyl F, by the ſpace F I, wherefore the proportion of the gravity of theſe two Liquors was as G H to F E.

This Experiment I tried with ſeveral other Liquors, and particularly with freſh Water and Salt (which I made by diſſolving Salt in warm Water) which two though they are nothing heterogeneous, yet before they would perfectly mix one with another, I made trial of the Experiment: Nay, letting the Tube wherein I tried the Experiment remain for many dayes, I obſerved them not to mix; but the ſuperficies of the freſh was rather more then leſs elevated above that of the Salt. Now the proportion of the gravity of Sea-water, to that of River-water, according to *Stevinus* and *Varenius*, and as I have ſince found pretty true by making trial my ſelf, is as 46. to 45. that is, 46. Ounces of the ſalt Wa-

ter will take up no more room then 45. of the fresh. Or reciprocally 45 pints of salt-water weigh as much as 46 of fresh.

But I found the proportion of Brine to fresh Water to be near 13 to 12: Supposing therefore G H M to represent the Sea, and F I the height of the Mountain above the Superficies of the Sea, F M a Cavern in the Earth, beginning at the bottom of the Sea, and terminated at the top of the Mountain, L M the Sand at the bottom, through which the Water is as it were strained, so as that the fresher parts are only permitted to transude, and the saline kept back; if therefore the proportion of G M to F M be as 45 to 46, then may the Cylinder of Salt-water G M make the Cylinder of Fresh-water to rise as high as E, and to run over at N. I cannot here stand to examine or confute their Opinion, who make the depth of the Sea, below its Superficies, to be no more perpendicularly measured then the height of the Mountains above it: 'Tis enough for me to say, there is no one of those that have asserted it, have experimentally known the perpendicular of either; nor shall I here determine, whether there may not be many other causes of the separation of the fresh water from the salt, as perhaps some parts of the Earth through which it is to pass, may contain a Salt, that mixing and uniting with the Sea-salt, may precipitate it; much after the same manner as the *Alkalizate* and *Acid Salts* mix and precipitate each other in the preparation of *Tartarum Vitriolatum*. I know not also whether the exceeding cold (that must necessarily be) at the bottom of the Water, may not help towards this separation, for we find, that warm Water is able to dissolve and contain more Salt, then the same cold; insomuch that Brines strongly impregnated by heat, if let cool, do suffer much of their Salt to subside and crystallize about the bottom and sides. I know not also whether the exceeding pressure of the parts of the Water one against another, may not keep the Salt from descending to the very bottom, as finding little or no room to insert it self between those parts, protruded so violently together, or else squeeze it upwads into the superiour parts of the Sea, where it may more easily obtain room for it self, amongst the parts of the Water, by reason that there is more heat and less pressure. To this Opinion I was somewhat the more induced by the relations I have met with in *Geographical Writers*, of drawing fresh Water from the bottom of the Sea, which is salt above. I cannot now stand to examine, whether this natural perpetual motion may not artificially be imitated: Nor can I stand to answer the Objections which may be made against this my Supposition: As, First, How it comes to pass, that there are sometimes salt Springs much higher then the Superficies of the Water? And, Secondly, Why Springs do not run faster and slower, according to the varying height made of the Cylinder of Sea-water, by the ebbing and flowing of the Sea?

As to the First, In short, I say, the fresh Water may receive again a saline Tincture near the Superficies of the Earth, by passing through some salt *Mines*, or else many of the saline parts of the Sea may be kept back, though not all.

And

And as to the Second, The ſame *Spring* may be fed and ſupplyed by divers *Caverns*, coming from very far diſtant parts of the *Sea*, ſo as that it may in one place be *high*, in another *low water*; and ſo by that means the *Spring* may be equally ſupply'd at all times. Or elſe the *Cavern* may be ſo ſtraight and narrow, that the water not having ſo ready and free paſſage through it, cannot upon ſo ſhort and quick mutations of preſſure, be able to produce any ſenſible effect at ſuch a diſtance. Beſides that, to confirm this *hypotheſis*, there are many *Examples* found in *Natural Hiſtorians*, of *Springs* that do ebb and flow like the Sea: As particularly, thoſe recorded by the Learned *Camden*, and after him by *Speed*, to be found in this *Iſland*: One of which, they relate to be on the Top of a Mountain, by the ſmall Village *Kilken* in *Flintſhire*, *Maris æmulus qui ſtatis temporibus ſuas evomit & reſorbet Aquas*; Which at certain times riſeth and falleth after the manner of the Sea. A Second in *Caermardenſhire*, near *Caermarden*, at a place called *Cantred Bichan*; *Qui* (*ut ſcribit Giraldus*) *naturali die bis undis deficiens*, *& toties exuberans*, *marinas imitatur inſtabilitates*; That twice in four and twenty hours ebbing and flowing, reſembleth the unſtable motions of the Sea. The *Phænomena* of which two may be eaſily made out, by ſuppoſing the *Cavern*, by which they are fed, to ariſe from the bottom of the next Sea. A Third, is a Well upon the River *Ogmore* in *Glamorganſhire*, and near unto *Newton*, of which *Camden* relates himſelf to be certified, by a Letter from a Learned Friend of his that obſerved it, *Fons abeſt hinc*, *&c.* The Letter is a little too long to be inſerted, but the ſubſtance is this; That this Well ebbs and flows quite contrary to the flowing and ebbing of the Sea in thoſe parts: for 'tis almoſt empty at Full Sea, but full at Low water. This may happen from the Channel by which it is ſupplied, which may come from the bottom of a Sea very remote from thoſe parts, and where the Tides are much differing from thoſe of the approximate ſhores. A Fourth, lies in *Weſtmorland*, near the River *Loder*; *Qui inſtar Euripi ſæpius in die reciprocantibus undis fluit & refluit*, which ebbs and flows many times a day. This may proceed from its being ſupplyed from many Channels, coming from ſeveral parts of the Sea, lying ſufficiently diſtant aſunder to have the times of High-water differing enough one from the other; ſo as that whenſoever it ſhall be High water over any of thoſe places, where theſe Channels begin, it ſhall likewiſe be ſo in the Well; but this is but a ſuppoſition.

A Seventh *Query* was, Whether the *diſſolution* or mixing of ſeveral bodies, whether fluid or ſolid, with ſaline or other Liquors, might not partly be attributed to this Principle of the congruity of thoſe bodies and their diſſolvents? As of Salt in Water, Metals in ſeveral *Menſtruums*, Unctuous Gums in Oyls, the mixing of Wine and Water, *&c.* And whether *precipitation* be not partly made from the ſame Principle of Incongruity? I ſay *partly*, becauſe there are in ſome Diſſolutions, ſome other Cauſes concurrent.

I ſhall laſtly make a much more ſeemingly ſtrange and unlikely *Query*; and that is, Whether this Principle, well examined and explained, may

not be found a *co-efficient* in the moſt conſiderable Operations of Nature? As in thoſe of *Heat*, and *Light*, and conſequently, of *Rarefaction* and *Condenſation*, *Hardneſs*, and *Fluidneſs*, *Perſpicuity* and *Opacouſneſs*, *Refractions* and *Colours*, *&c.* Nay, I know not whether there may be many things done in Nature, in which this may not (be ſaid to) have a Finger? This I have in ſome other paſſages of this Treatiſe further enquired into and ſhewn, that as well *Light* as *Heat* may be cauſed by *corroſion*, which is applicable to *congruity*, and conſequently all the reſt will be but *ſubſequents:* In the mean time I would not willingly be guilty of that *Error*, which the thrice Noble and Learned *Verulam* juſtly takes notice of, as ſuch, and calls *Philoſophiæ Genus Empiricum*, *quod in paucorum Experimentorum Anguſtiis & Obſcuritate fundatum eſt.* For I neither conclude from one ſingle Experiment, nor are the Experiments I make uſe of, all made upon one Subject: Nor wreſt I any Experiment to make it *quadrare* with any preconceiv'd Notion. But on the contrary, I endeavour to be converſant in divers kinds of Experiments, and all and every one of thoſe Trials, I make the Standards or Touchſtones, by which I try all my former Notions, whether they hold out in weight, and meaſure, and touch, *&c.* For as that Body is no other then a Counterfeit Gold, which wants any one of the Proprieties of Gold, (ſuch as are the Malleableneſs, Weight, Colour, Fixtneſs in the Fire, Indiſſolubleneſs in *Aqua fortis*, and the like) though it has all the other; ſo will all thoſe Notions be found to be falſe and deceitful, that will not undergo all the Trials and Teſts made of them by Experiments. And therefore ſuch as will not come up to the deſired *Apex* of Perfection, I rather wholly reject and take new, then by piecing and patching, endeavour to retain the old, as knowing ſuch things at beſt to be but lame and imperfect. And this courſe I learned from Nature; whom we find neglectful of the old Body, and ſuffering its Decaies and Infirmities to remain without repair, and altogether ſollicitous and careful of perpetuating the *Species* by new *Individuals*. And it is certainly the moſt likely way to erect a glorious Structure and Temple to *Nature*, ſuch as ſhe will be found (by any *zealous Votary*) to reſide in; to begin to build a new upon a ſure Foundation of Experiments.

But to digreſs no further from the conſideration of the *Phænomena*, more immediately explicable by this Experiment, we ſhall proceed to ſhew, That, as to the riſing of Water in a *Filtre*, the reaſon of it will be manifeſt to him, that does take notice, that a *Filtre* is conſtituted of a great number of ſmall long ſolid bodies, which lie ſo cloſe together, that the Air in its getting in between them, doth loſe of its preſſure that it has againſt the *Fluid* without them, by which means the Water or Liquor not finding ſo ſtrong a reſiſtance between them as is able to counter-ballance the preſſure on its ſuperficies without, is raiſed upward, till it meet with a preſſure of the Air which is able to hinder it. And as to the Riſing of Oyl, melted Tallow, Spirit of Wine, *&c.* in the Week of a Candle or Lamp, it is evident, that it differs in nothing from the former, ſave only in this, that in a *Filtre* the Liquor deſcends and runs away by another part; and in the Week the Liquor is diſperſed and carried away by the

Flame;

Flame; fomething there is afcribable to the Heat, for that it may rarifie the more volatil and fpirituous parts of thofe combuftible Liquors, and fo being made lighter then the Air, it may be protruded upwards by that more ponderous fluid body in the Form of Vapours; but this can be afcribed to the afcenfion of but a very little, and moft likely of that only which afcends without the Week. As for the Rifing of it in a Spunge, Bread, Cotton, *&c.* above the fuperficies of the fubjacent Liquor; what has been faid about the *Filtre* (if confidered) will eafily fuggeft a reafon, confidering that all thefe bodies abound with fmall holes or pores.

From this fame Principle alfo (*viz. the unequal preffure of the Air againft the unequal fuperficies of the water*) proceeds the caufe of the acceffion or incurfion of any floating body againft the fides of the containing Veffel, or the *appropinquation* of two floating bodies, as *Bubbles, Corks, Sticks, Straws, &c.* one towards another. As for inftance, Take a Glafs-jar, fuch as A B in the feventh *Figure*, and filling it pretty near the top with water, throw into it a fmall round piece of Cork, as C, and plunge it all over in water, that it be wet, fo as that the water may rife up by the fides of it, then placing it any where upon the fuperficies, about an inch, or one inch and a quarter from any fide, and you fhall perceive it by degrees to make *perpendicularly* toward the neareft part of the fide, and the nearer it approaches, the fafter to be moved; the reafon of which *Phænomenon* will be found no other then this, that the Air has a greater preffure againft the middle of the *fuperficies*, then it has againft thofe parts that approach nearer, and are *contiguous* to the fides. Now that the preffure is greater, may (as I fhewed before in the explication of the third *Figure*) be evinced from the flatting of the water in the middle, which arifes from the gravity of the under *fluid*: for fince, as I fhewed before, if there were no gravity in the under *fluid*, or that it were equal to that of the upper, the terminating Surface would be *Spherical*, and fince it is the additional preffure of the gravity of water that makes it fo flat, it follows, that the preffure upon the middle muft be greater then towards the fides. Hence the Ball having a ftronger preffure againft that fide of it which refpects the middle of the *fuperficies*, then againft that which refpects the *approximate* fide, muft neceffarily move towards that part, from whence it finds leaft refiftance, and fo be *accelerated*, as the refiftance decreafes. Hence the more the water is raifed under that part of its way it is paffing above the middle, the fafter it is moved: And therefore you will find it to move fafter in E then in D, and in D then in C. Neither could I find the floating fubftance to be moved at all, until it were placed upon fome part of the *Superficies* that was fenfibly elevated above the height of the middle part. Now that this may be the true caufe, you may try with a blown Bladder, and an exactly round Ball upon a very fmooth fide of fome pliable body, as *Horn* or *Quickfilver*. For if the Ball be placed under a part of the Bladder which is upon one fide of the middle of its preffure, and you prefs ftrongly againft the Bladder, you fhall find the Ball moved from the middle towards the fides.

Having

Having therefore ſhewn the reaſon of the motion of any float towards the ſides, the reaſon of the incurſion of any two floating bodies will eaſily appear: For the riſing of the water againſt the ſides of either of them,is an Argument ſufficient,to ſhew the preſſure of the Air to be there leſs,then it is further from it,where it is not ſo much elevated ; and therefore the reaſon of the motion of the other toward it, will be the ſame as towards the ſide of the Glaſs; only here from the ſame reaſon, they are mutually moved toward each other, whereas the ſide of the Glaſs in the former remains fixt. If alſo you gently fill the Jar ſo full with water, that the water is *protuberant* above the ſides, the ſame piece of Cork that before did haſten towards the ſides, does now fly from it as faſt towards the middle of the Superficies; the reaſon of which will be found no other then this, that the preſſure of the Air is ſtronger againſt the ſides of the Superficies G and H, then againſt the middle I; for ſince, as I ſhewed before, the Principle of congruity would make the terminating Surface Spherical, and that the flatting of the Surface in the middle is from the abatement of the waters preſſure outwards, by the contrary indeavour of its gravity; it follows that the preſſure in the middle muſt be leſs then on the ſides; and therefore the conſecution will be the ſame as in the former. It is very odd to one that conſiders not the reaſon of it, to ſee two floating bodies of wood to approach each other,as though they were indued with ſome magnetical vigour; which brings into my mind what I formerly tried with a piece of Cork or ſuch like body, which I ſo ordered, that by putting a little ſtick into the ſame water, one part of the ſaid Cork would approach and make toward the ſtick, whereas another would diſcede and fly away,nay it would have a kind of verticity, ſo as that if the *Æquator* (as I may ſo ſpeak) of the Cork were placed towards the ſtick, if let alone, it would inſtantly turn its appropriate Pole toward it,and then run a-tilt at it:and this was done only by taking a dry Cork, and wetting one ſide of it with one ſmall ſtroak; for by this means gently putting it upon the water, it would depreſs the ſuperficies on every ſide of it that was dry, and therefore the greateſt preſſure of the Air, being near thoſe ſides,cauſed it either to chaſe away,or elſe to fly off from any other floating body, whereas that ſide only, againſt which the water aſcended, was thereby able to attract.

It remains only, that I ſhould determine how high the Water or other Liquor may by this means be raiſed in a ſmaller Pipe above the Superficies of that without it, and at what height it may be ſuſtained: But to determine this, will be exceeding difficult, unleſs I could certainly know how much of the Airs preſſure is taken off by the ſmalneſs of ſuch and ſuch a Pipe,and whether it may be wholly taken off,that is,whether there can be a hole or pore ſo ſmall, into which Air could not at all enter, though water might with its whole force; for were there ſuch, 'tis manifeſt, that the water might riſe in it to ſome five or ſix and thirty Engliſh Foot high. I know not whether the capillary Pipes in the bodies of ſmall Trees, which we call their *Microſcopical pores*,may not be ſuch; and whether the congruity of the ſides of the Pore may not yet draw the juyce even

even higher then the Air was able by its bare preſſure to raiſe it: For, Congruity is a principle that not only unites and holds a body joyned to it, but, which is more, attracts and draws a body that is very near it, and holds it above its uſual height.

And this is obvious even in a drop of water ſuſpended under any Similar or Congruous body: For, beſides the ambient preſſure that helps to keep it ſuſtein'd, there is the Congruity of the bodies that are contiguous. This is yet more evident in Tenacious and Glutinous bodies; ſuch as Gummous Liquors, Syrups, Pitch, and Roſin melted, &c. Tar, Turpentine, Balſom, Bird-lime, &c. for there it is evident, that the Parts of the tenacious body, as I may ſo call it, do ſtick and adhere ſo cloſely together, that though drawn out into long and very ſlender Cylinders, yet they will not eaſily relinquiſh one another; and this, though the bodies be *aliquatenus* fluid, and in motion by one another; which, to ſuch as conſider a fluid body only as its parts are in a confuſed irregular motion, without taking in alſo the congruity of the parts one among another, and incongruity to ſome other bodies, does appear not a little ſtrange. So that beſides the incongruity of the ambient fluid to it, we are to conſider alſo the congruity of the parts of the contein'd fluid one with another.

And this Congruity (that I may here a little further explain it) is both a Tenaceous and an Attractive power; for the Congruity, in the Vibrative motions, may be the cauſe of all kind of attraction, not only Electrical, but Magnetical alſo, and therefore it may be alſo of Tenacity and Glutinouſneſs. For, from a perfect congruity of the motions of two diſtant bodies, the intermediate fluid particles are ſeparated and droven away from between them, and thereby thoſe congruous bodies are, by the incompaſſing mediums, compell'd and forced neerer together; wherefore that attractiveneſs muſt needs be ſtronger, when, by an immediate contact, they are forc'd to be exactly the ſame: As I ſhew more at large in my *Theory* of the *Magnet*. And this hints to me the reaſon of the ſuſpenſion of the *Mercury* many inches, nay many feet, above the uſual ſtation of 30 inches. For the parts of *Quick-ſilver*, being ſo very ſimilar and congruous to each other, if once united, will not eaſily ſuffer a divulſion: And the parts of water, that were any wayes *heterogeneous*, being by *exantlation* or rarefaction exhauſted, the remaining parts being alſo very ſimilar, will not eaſily part neither. And the parts of the Glaſs being ſolid, are more difficultly disjoyn'd; and the water, being ſomewhat ſimilar to both, is, as it were, a medium to unite both the *Glaſs* and the *Mercury* together. So that all three being united, and not very diſſimilar, by means of this contact, if care be taken that the Tube in erecting be not ſhogged, the *Quickſilver* will remain ſuſpended, notwithſtanding its contrary indeavour of Gravity, a great height above its ordinary Station; but if this immediate Contact be removed, either by a meer ſeparation of them one from another by the force of a ſhog, whereby the other becomes imbodied between them, and licks up from the ſurface ſome agil parts, and ſo hurling them makes them air; or elſe by

by ſome ſmall heterogeneous agil part of the Water, or Air, or Quick-ſilver, which appears like a bubble, and by its jumbling to and fro there is made way for the *heterogeneous Æther* to obtrude it ſelf between the Glaſs and either of the other Fluids, the Gravity of *Mercury precipitates* it downward with very great violence ; and if the Veſſel that holds the reſtagnating *Mercury* be convenient, the *Mercury* will for a time *vibrate* to and fro with very large *reciprocations*, and at laſt will remain kept up by the preſſure of the external Air at the height of neer thirty inches. And whereas it may be objected, that it cannot be, that the meer imbodying of the *Æther* between theſe bodies can be the cauſe, ſince the *Æther* having a free paſſage alwayes, both through the Pores of the Glaſs, and through thoſe of the Fluids, there is no reaſon why it ſhould not make a ſeparation at all times whilſt it remains ſuſpended, as when it is violently diſ-joyned by a ſhog. To this I anſwer, That though the *Æther* paſſes between the Particles, that is, through the Pores of bodies, ſo as that any chaſme or ſeparation being made, it has infinite paſſages to admit its entry into it, yet ſuch is the tenacity or attractive virtue of Congruity, that till it be overcome by the meer ſtrength of Gravity, or by a ſhog aſſiſting that Conatus of Gravity, or by an agil Particle, that is like a leaver agitated by the *Æther* ; and thereby the parts of the congruous ſubſtances are ſeparated ſo far aſunder, that the ſtrength of congruity is ſo far weakened, as not to be able to reunite them, the parts to be taken hold of being removed out of the attractive Sphere, as I may ſo ſpeak, of the congruity ; ſuch, I ſay, is the tenacity of congruity, that it retains and holds the almoſt contiguous Particles of the Fluid, and ſuffers them not to be ſeparated, till by meer force that attractive or retentive faculty be overcome: But the ſeparation being once made beyond the Sphere of the attractive activity of congruity, that virtue becomes of no effect at all, but the *Mercury* freely falls downwards till it meet with a reſiſtance from the preſſure of the *ambient* Air, able to reſiſt its gravity, and keep it forced up in the Pipe to the height of about thirty inches.

Thus have I gently raiſed a Steel *pendulum* by a Loadſtone to a great Angle, till by the ſhaking of my hand I have chanced to make a ſeparation between them, which is no ſooner made, but as if the Loadſtone had retained no attractive virtue, the *Pendulum* moves freely from it towards the other ſide. So vaſt a difference is there between the attractive virtue of the *Magnet* when it acts upon a contiguous and upon a disjoyned body: and much more muſt there be between the attractive virtues of congruity upon a contiguous and disjoyned body ; and in truth the attractive virtue is ſo little upon a body disjoyned, that though I have with a *Microſcope* obſerved very diligently, whether there were any extraordinary *protuberance* on the ſide of a drop of water that was exceeding neer to the end of a green ſtick, but did not touch it, I could not perceive the leaſt ; though I found, that as ſoon as ever it toucht it the whole drop would preſently unite it ſelf with it ; ſo that it ſeems an abſolute contact is requiſite to the exerciſing of the tenacious faculty of congruity.

Obſerv.

Obſerv. VII. *Of ſome* Phænomena *of Glaſs drops.*

THeſe *Glaſs Drops* are ſmall parcels of coarſe green Glaſs taken out of the Pots that contain the *Metal* (as they call it) in fuſion, upon the end of an Iron Pipe ; and being exceeding hot, and thereby of a kind of ſluggiſh fluid Conſiſtence, are ſuffered to drop from thence into a Bucket of cold Water, and in it to lye till they be grown ſenſibly cold.

Some of theſe I broke in the open air, by ſnapping off a little of the ſmall ſtem with my fingers, others by cruſhing it with a ſmall pair of Plyers ; which I had no ſooner done, then the whole bulk of the drop flew violently, with a very brisk noiſe, into multitudes of ſmall pieces, ſome of which were as ſmall as duſt, though in ſome there were remaining pieces pretty large, without any flaw at all, and others very much flaw'd, which by rubbing between ones fingers was eaſily reduced to duſt ; theſe diſperſed every way ſo violently, that ſome of them pierced my skin. I could not find, either with my naked Eye, or a *Microſcope*, that any of the broken pieces were of a regular figure, nor any one like another, but for the moſt part thoſe that flaw'd off in large pieces were prettily branched.

The ends of others of theſe drops I nipt off whilſt all the bodies and ends of them lay buried under the water, which, like the former, flew all to pieces with as brisk a noiſe, and as ſtrong a motion.

Others of theſe I tried to break, by grinding away the blunt end, and though I took a ſeemingly good one, and had ground away neer two thirds of the Ball, yet would it not fly to pieces, but now and then ſome ſmall rings of it would ſnap and fly off, not without a brisk noiſe and quick motion, leaving the Surface of the drop whence it flew very prettily branched or creaſed, which was eaſily diſcoverable by the *Microſcope*. This drop, after I had thus ground it, without at all impairing the remnant that was not ground away, I cauſed to fly immediately all into ſand upon the nipping off the very tip of its ſlender end.

Another of theſe drops I began to grind away at the ſmaller end, but had not worn away on the ſtone above a quarter of an inch before the whole drop flew with a brisk crack into ſand or ſmall duſt ; nor would it have held ſo long, had there not been a little flaw in the piece that I ground away, as I afterwards found.

Several others of theſe drops I covered over with a thin but very tuff skin of *Icthyocolla*, which being very tough and very tranſparent, was the moſt convenient ſubſtance for theſe tryals that I could imagine, having dipt, I ſay, ſeveral of theſe drops in this tranſparent Glue whilſt hot, and ſuffering them to hang by a ſtring tied about the end of them till they were cold, and the skin pretty tough ; then wrapping all the body of the

drop (leaving out only the very tip) in fine ſupple Kids-leather very cloſely, I nipped off the ſmall top, and found, as I expected, that notwithſtanding this skin of Glue, and the cloſe wrapping up in Leather, upon the breaking of the top, the drop gave a crack like the reſt, and gave my hand a pretty brisk impulſe: but yet the skin and leather was ſo ſtrong as to keep the parts from flying out of their former poſture; and, the skin being tranſparent, I found that the drop retained exactly its former figure and poliſh, but was grown perfectly opacous and all over flaw'd, all thoſe flaws lying in the manner of rings, from the bottom or blunt end, to the very top or ſmall point. And by ſeveral examinations with a *Microſcope*, of ſeveral thus broken, I found the flaws, both within the body of the drop, and on the outward ſurface, to lye much in this order.

Let A B in the Figure X of the fourth Scheme repreſent the drop caſed over with *Icthyocolla* or *Iſinglaſs*, and (by being ordered as is before preſcribed) crazed or flawed into pieces, but by the skin or caſe kept in its former figure, and each of its flawed parts preſerved exactly in its due poſture; the outward appearance of it ſomewhat plainly to the naked eye, but much more conſpicuous if viewed with a ſmall ſenſs appeared much after this ſhape. That is, the blunt end B for a pretty breadth, namely, as far as the Ring C C C ſeemed irregularly flawed with divers clefts, which all ſeemed to tend towards the Center of it, being, as I afterwards found, and ſhall anon ſhew in the deſcription of the figure Y, the Baſis, as it were, of a Cone, which was terminated a little above the middle of the drop, all the reſt of the Surface from C C C to A was flawed with an infinite number of ſmall and parallel Rings, which as they were for the moſt part very round, ſo were they very thick and cloſe together, but were not ſo exactly flaw'd as to make a perfect Ring, but each circular part was by irregular cracks flawed likewiſe into multitudes of irregular flakes or tiles; and this order was obſerved likewiſe the whole length of the neck,

Now though I could not ſo exactly cut this *conical Body* through the *Axis*, as is repreſented by the figure Y; yet by *anatomizing*, as it were, of ſeveral, and taking notice of divers particular circumſtances, I was informed, that could I have artificially divided a flaw'd drop through the *Axis* or *Center*. I ſhould with a *Microſcope* have found it to appear much of this form, where A ſignifies the *Apex*, and B the blunt end, C C the Cone of the Baſis, which is terminated at T the top or end of it, which ſeems to be the very middle of the blunt end, in which, not only the conical body of the Baſis C C is terminated, but as many of the parts of the drop as reach as high as D D.

And it ſeemed to be the head or beginning of a Pith, as it were, or a a part of the body which ſeemed more ſpungy then the reſt, and much more irregularly flawed, which from T aſcended by E E, though leſs viſible, into the ſmall neck towards A. The Grain, as it were, of all the flaws, that from all the outward Surface A D C C D A, was much the ſame, as is repreſented by the black ſtrokes that meet in the middle D T, D T, D E, D E, *&c.*

Nor

Nor is this kind of Grain, as I may call it, peculiar to Glaſs drops thus quenched; for (not to mention *Coperas-ſtones*, and divers other *Marchaſites* and *Minerals*, which I have often taken notice of to be in the very ſame manner flaked or grained, with a kind of Pith in the middle) I have obſerved the ſame in all manner of caſt Iron, eſpecially the coarſer ſort, ſuch as Stoves, and Furnaces, and Backs, and Pots are made of: For upon the breaking of any of thoſe Subſtances it is obvious to obſerve, how from the out-ſides towards the middle, there is a kind of Radiation or Grain much reſembling this of the Glaſs-drop; but this Grain is moſt conſpicuous in Iron-bullets, if they be broken: the ſame *Phænomena* may be produced by caſting *regulus* of *Antimony* into a Bullet-mold, as alſo with *Glaſs of Antimony*, or with almoſt any ſuch kind of *Vitrified ſubſtance*, either caſt into a cold Mold or poured into Water.

Others of theſe Drops I heat red hot in the fire,and then ſuffered them to cool by degrees. And theſe I found to have quite loſt all their *fulminating* or flying quality, as alſo their hard, brittle and ſpringy texture; and to emerge of a much ſofter temper, and much eaſier to be broken or ſnapt with ones finger;but its ſtrong and brittle quality was quite deſtroyed, and it ſeemed much of the ſame conſiſtence with other green Glaſs well nealed in the Oven.

The Figure and bigneſs of theſe for the moſt part was the ſame with that of the Figure Z; that is,all the ſurface of them was very ſmooth and poliſht,and for the moſt part round, but very rugged or knobbed about D, and all the length of the ſtem was here and there pitted or flatted. About D, which is at the upper part of the drop under that ſide of the ſtem which is concave, there uſually was made ſome one or more little Hillocks or Prominences. The drop it ſelf, before it be broken, appears very tranſparent, and towards the middle of it, to be very full of ſmall Bubbles, of ſome kind of aerial ſubſtance, which by the refraction of the outward ſurface appear much bigger then really they are; and this may be in good part removed, by putting the drop under the ſurface of clear Water, for by that means moſt part of the refraction of the convex Surface of the drop is deſtroyed, and the bubbles will appear much ſmaller. And this, by the by, minds me of the appearing magnitude of the *aperture* of the *iris*, or *pupil* of the eye, which though it appear, and be therefore judged very large, is yet not above a quarter of the bigneſs it appears of, by the *lenticular* refraction of the *Cornea.*

The cauſe of all which *Phænomena* I imagine to be no other then this, That the Parts of the Glaſs being by the exceſſive heat of the fire kept off and ſeparated one from another, and thereby put into a kind of ſluggiſh fluid conſiſtence, are ſuffered to drop off with that heat or agitation remaining in them, into cold Water; by which means the outſides of the drop are preſently cool'd and *cruſted*, and are thereby made of a looſe texture,becauſe the parts of it have not time to ſettle themſelves leiſurely together, and ſo to lie very cloſe together: And the innermoſt parts of the drop, retaining ſtill much of their former heat and agitations, remain

of a loofe texture alfo,and,according as the cold ftrikes inwards from the bottom and fides, are quenched, as it were, and made rigid in that very pofture wherein the cold finds them. For the parts of the *cruft* being already hardened, will not fuffer the parts to fhrink any more from the outward Surface inward; and though it fhrink a little by reafon of the fmall parcels of fome Aerial fubftances difperfed through the matter of the Glafs, yet that is not neer fo much as it appears (as I juft now hinted;) nor if it were,would it be fufficient for to confolidate and condenfe the body of Glafs into a *tuff* and clofe *texture*, after it had been fo exceffively rarified by the heat of the glafs-Furnace.

But that there may be fuch an expanfion of the aerial fubftance contained in thofe little *blebbs* or bubbles in the body of the drop, this following Experiment will make more evident.

Take a fmall Glafs-Cane about a foot long, feal up one end of it *hermetically*,then put in a very fmall bubble of Glafs, almoft of the fhape of an Effence-viol with the open mouth towards the fealed end, then draw out the other end of the Pipe very fmall,and fill the whole Cylinder with water, then fet this Tube by the Fire till the Water begin to boyl, and the Air in the bubble be in good part rarified and driven out, then by fucking at the fmalling Pipe, more of the Air or vapours in the bubble may be fuck'd out, fo that it may fink to the bottom; when it is funk to the bottom,in the flame of a Candle,or Lamp,nip up the flender Pipe and let it cool: whereupon it is obvious to obferve, firft, that the Water by degrees will fubfide and fhrink into much lefs room: Next, that the Air or vapours in the Glafs will expand themfelves fo, as to buoy up the little Glafs: Thirdly, that all about the infide of the Glafs-pipe there will appear an infinite number of fmall bubbles,which as the Water grows colder and colder will fwell bigger and bigger, and many of them buoy themfelves up and break at the top.

From this *Difceding* of the heat in Glafs drops,that is, by the quenching or cooling Irradiations propagated from the Surface upwards and inwards, by the lines C T, C T, D T, D E, *&c.* the bubbles in the drop have room to expand themfelves a little, and the parts of the Glafs contract themfelves; but this operation being too quick for the fluggifh parts of the Glafs, the contraction is performed very unequally and irregularly, and thereby the Particles of the Glafs are bent, fome one way, and fome another, yet fo as that moft of them draw towards the Pith or middle T E E E, or rather from that outward: fo that they cannot *extricate* or unbend themfelves, till fome part of T E E E be broken and loofened, for all the parts about that are placed in the manner of an Arch, and fo till their hold at T E E E be loofened they cannot fly afunder, but uphold, and fhelter, and fix each other much like the ftones in a Vault, where each ftone does concurre to the ftability of the whole Fabrick, and no one ftone can be taken away but the whole Arch falls.And wherefoever any of thofe radiating wedges D T D, *&c.* are removed, which are the component parts of this Arch,the whole Fabrick prefently falls to

pieces;

pieces; for all the Springs of the ſeveral parts are ſet at liberty; which immediately extricate themſelves and fly aſunder every way; each part by its ſpring contributing to the darting of it ſelf and ſome other contiguous part. But if this drop be heat ſo hot as that the parts by degrees can unbend themſelves, and be ſettled and annealed in that poſture, and be then ſuffered gently to ſubſide and cool; The parts by this nealing loſing their ſpringineſs, conſtitute a drop of a more ſoft but leſs brittle texture, and the parts being not at all under a flexure, though any part of the middle or Pith TEEE be broken, yet will not the drop at all fly to pieces as before.

This Conjecture of mine I ſhall indeavour to make out by explaining each particular Aſſertion with *analogous* Experiments: The Aſſertions are theſe.

Firſt, That the parts of the Glaſs, whilſt in a fluid Conſiſtence and hot, are more rarified, or take up more room, then when hard and cold.

Secondly, That the parts of the drop do ſuffer a twofold contraction.

Thirdly, That the dropping or quenching the glowing metal in the Water makes it of a hard, ſpringing, and rarified texture.

Fourthly, That there is a flexion or force remaining upon the parts of the Glaſs thus quenched, from which they indeavour to extricate themſelves.

Fifthly, That the Fabrick of the drop, that is able to hinder the parts from extricating themſelves, is *analogus* to that of an Arch.

Sixthly, That the ſudden flying aſunder of the parts proceeds from their ſpringineſs.

Seventhly, That a gradual heating and cooling does anneal or reduce the parts of Glaſs to a texture that is more looſe, and eaſilier to be broken, but not ſo brittle.

That the firſt of theſe is true may be gathered from this, That *Heat is a property of a body ariſing from the motion or agitation of its parts*; and therefore whatever body is thereby toucht muſt neceſſarily receive ſome part of that motion, whereby its parts will be ſhaken and agitated, and ſo by degrees free and extricate themſelves from one another, and each part ſo moved does by that motion *exert a conatus* of *protruding* and diſplacing all the adjacent Particles. Thus Air included in a veſſel, by being heated will burſt it to pieces. Thus have I broke a Bladder held over the fire in my hand, with ſuch a violence and noiſe, that it almoſt made me deaf for the preſent, and much ſurpaſſed the noiſe of a Musket: The like have I done by throwing into the fire ſmall glaſs Bubbles hermetically ſealed, with a little drop of Water included in them. Thus Water alſo, or any other Liquor, included in a convenient veſſel, by being warmed, manifeſtly expands it ſelf with a very great violence, ſo as to break the ſtrongeſt veſſel, if when heated it be narrowly impriſoned in it.

This

This is very manifeſt by the *ſealed Thermometers*, which I have, by ſeveral tryals, at laſt brought to a great certainty and tenderneſs: for I have made ſome with ſtems above four foot long, in which the expanding Liquor would ſo far vary, as to be very neer the very top in the heat of Summer, and prety neer the bottom at the coldeſt time of the Winter. The Stems I uſe for them are very thick, ſtraight, and even Pipes of Glaſs, with a very ſmall *perforation*, and both the head and body I have made on purpoſe at the Glaſs-houſe, of the ſame metal whereof the Pipes are drawn: theſe I can eaſily in the flame of a Lamp, urged with the blaſt of a pair of Bellows, ſeal and cloſe together, ſo as to remain very firm, cloſe and even; by this means I joyn on the body firſt, and then fill both it and a part of the ſtem, proportionate to the length of the ſtem and the warmth of the ſeaſon I fill it in, with the beſt rectified *Spirit of Wine* highly *ting'd* with the lovely colour of *Cocheneel*, which I deepen the more by pouring ſome drops of common *Spirit of Urine*, which muſt not be too well rectified, becauſe it will be apt to make the Liquor to curdle and ſtick in the ſmall perforation of the ſtem. This Liquor I have upon tryal found the moſt tender of any ſpirituous Liquor, and thoſe are much more ſenſibly affected with the variations of heat and cold then other more flegmatick and ponderous Liquors, and as capable of receiving a deep tincture, and keeping it, as any Liquor whatſoever; and (which makes it yet more acceptable) is not ſubject to be frozen by any cold yet known. When I have thus filled it, I can very eaſily in the forementioned flame of a Lamp ſeal and joyn on the head of it.

Then, for graduating the ſtem, I fix that for the beginning of my diviſion where the ſurface of the liquor in the ſtem remains when the ball is placed in common diſtilled water, that is ſo cold that it juſt begins to freeze and ſhoot into flakes; and that mark I fix at a convenient place of the ſtem, to make it capable of exhibiting very many degrees of cold, below that which is requiſite to freeze water: the reſt of my diviſions, both above and below this (which I mark with a [o] or nought) I place according to the Degrees of *Expanſion*, or *Contraction* of the Liquor in proportion to the bulk it had when it indur'd the newly mention'd freezing cold. And this may be very eaſily and accurately enough done by this following way; Prepare a Cylindrical veſſel of very thin plate Braſs or Silver, A B C D of the figure Z; the Diameter A B of whoſe cavity let be about two inches, and the depth B C the ſame; let each end be cover'd with a flat and ſmooth plate of the ſame ſubſtance, cloſely ſoder'd on, and in the midſt of the upper cover make a pretty large hole E F, about the bigneſs of a fifth part of the Diameter of the other; into this faſten very well with cement a ſtraight and even Cylindrical pipe of Glaſs, E F G H, the Diameter of whoſe cavity let be exactly one tenth of the Diameter of the greater Cylinder. Let this pipe be mark'd at G H with a Diamant, ſo that G from E may be diſtant juſt two inches, or the ſame height with that of the cavity of the greater Cylinder, then divide the length E G exactly into 10 parts, ſo the capacity of the hollow of each of theſe diviſions will be $\frac{1}{1000}$ part of the capacity of the greater Cylinder.

der. This veſſel being thus prepared, the way of marking and graduating the *Thermometers* may be very eaſily thus performed:

Fill this Cylindrical veſſel with the ſame liquor wherewith the *Thermometers* are fill'd, then place both it and the *Thermometer* you are to *graduate*, in water that is ready to be frozen, and bring the ſurface of the liquor in the *Thermometer* to the firſt marke or [o]; then ſo proportion the liquor in the Cylindrical veſſel, that the ſurface of it may juſt be at the lower end of the ſmall glaſs-Cylinder; then very gently and gradually warm the water in which both the *Thermometer* and this Cylindrical veſſel ſtand, and as you perceive the ting'd liquor to riſe in both ſtems, with the point of a Diamond give ſeveral marks on the ſtem of the *Thermometer* at thoſe places, which by comparing the expanſion in both Stems, are found to correſpond to the diviſions of the cylindrical veſſel, and having by this means marked ſome few of theſe diviſions on the Stem, it will be very eaſie by theſe to mark all the reſt of the Stem, and accordingly to aſſign to every diviſion a proper character.

A *Thermometer*, thus marked and prepared, will be the fitteſt Inſtrument to make a Standard of heat and cold that can be imagined. For being ſealed up, it is not at all ſubject to variation or waſting, nor is it liable to be changed by the varying preſſure of the Air, which all other kind of *Thermometers* that are open to the Air are liable to. But to proceed.

This property of Expanſion with Heat, and Contraction with Cold, is not peculiar to Liquors only, but to all kind of ſolid Bodies alſo, eſpecially Metals, which will more manifeſtly appear by this Experiment.

Take the Barrel of a Stopcock of Braſs, and let the Key, which is well fitted to it,be riveted into it,ſo that it may ſlip,and be eaſily turned round, then heat this Cock in the fire, and you will find the Key ſo ſwollen, that you will not be able to turn it round in the Barrel; but if it be ſuffered to cool again, as ſoon as it is cold it will be as movable, and as eaſie to be turned as before.

This Quality is alſo very obſervable in *Lead*, *Tin*, *Silver*, *Antimony*, *Pitch*,*Roſin*,*Bees-wax*,*Butter*,and the like; all which,if after they be melted you ſuffer gently to cool, you ſhall find the parts of the upper Surface to ſubſide and fall inwards, loſing that plumpneſs and ſmoothneſs it had whilſt in fuſion. The like I have alſo obſerved in the cooling of *Glaſs of Antimony*, which does very neer approach the nature of Glaſs,

But becauſe theſe are all Examples taken from other materials then Glaſs,and argue only, that poſſibly there may be the like property alſo in Glaſs, not that really there is; we ſhall by three or four Experiments indeavour to manifeſt that alſo.

And the Firſt is an Obſervation that is very obvious even in theſe very drops,to wit,that they are all of them terminated with an unequal or irregular Surface, eſpecially about the ſmaller part of the drop, and the whole length of the ſtem; as about D, and from thence to A, the whole Surface, which would have been round if the drop had cool'd leiſurely, is, by being quenched haſtily,very irregularly flatted and pitted; which

I ſuppoſe proceeds partly from the Waters unequally cooling and preſſing the parts of the drop, and partly from the ſelf-contracting or ſubſiding quality of the ſubſtance of the Glaſs: For the vehemency of the heat of the drop cauſes ſuch ſudden motions and bubbles in the cold Water,that ſome parts of the Water bear more forcibly againſt one part then againſt another, and conſequently do more ſuddenly cool thoſe parts to which they are contiguous.

A Second Argument may be drawn from the Experiment of cutting Glaſſes with a hot Iron. For in that Experiment the top of the Iron heats, and thereby rarifies the parts of the Glaſs that lie juſt before the crack, whence each of thoſe agitated parts indeavouring to expand its ſelf and get elbow-room, thruſts off all the reſt of the contiguous parts, and conſequently promotes the crack that was before begun.

A Third Argument may be drawn from the way of producing a crack in a ſound piece or plate of Glaſs, which is done two wayes, either Firſt, by ſuddenly heating a piece of Glaſs in one place more then in another. And by this means *Chymiſts* uſually cut off the necks of Glaſs-bodies, by two kinds of Inſtruments, either by a glowing hot round Iron-Ring, which juſt incompaſſes the place that is to be cut, or elſe by a *Sulphur'd* Threed,which is often wound about the place where the ſeparation is to be made,and then fired. Or Secondly,A Glaſs may be cracked by cooling it ſuddenly in any place with Water, or the like, after it has been all leiſurely and gradually heated very hot. Both which *Phænomena* ſeem manifeſtly to proceed from the *expanſion* and contraction of the parts of the Glaſs, which is alſo made more probable by this circumſtance which I have obſerved, that a piece of common window-glaſs being heated in the middle very ſuddenly with a live Coal or hot Iron,does uſually at the firſt crack fall into pieces,whereas if the Plate has been gradually heated very hot, and a drop of cold Water and the like be put on the middle of it, it only flaws it, but does not break it aſunder immediately.

A Fourth Argument may be drawn from this Experiment; Take a Glaſs-pipe, and fit into it a ſolid ſtick of Glaſs, ſo as it will but juſt be moved in it. Then by degrees heat them whilſt they are one within another,and they will grow ſtiffer, but when they are again cold,they will be as eaſie to be turned as before. This Expanſion of Glaſs is more manifeſt in this Experiment.

Take a ſtick of Glaſs of a conſiderable length,and fit it ſo between the two ends or ſcrews of a Lath,that it may but juſt eaſily turn,and that the very ends of it may be juſt toucht and ſuſteined thereby; then applying the flame of the Candle to the middle of it, and heating it hot, you will preſently find the Glaſs to ſtick very faſt on thoſe points, and not without much difficulty to be convertible on them, before that by removing the flame for a while from it, it be ſuffered to cool, and then you will find it as eaſie to be turned round as at the firſt.

From all which Experiments it is very evident, that all thoſe Bodies, and particularly Glaſs, ſuffers an Expanſion by Heat, and that a very conſiderable

ſiderable one,whilſt they are in a ſtate of Fuſion. For *Fluidity*,as I elſewhere mention, *being nothing but an effect of a very ſtrong and quick ſhaking motion, whereby the parts are,as it were,looſened from each other,and conſequently leave an interjacent ſpace or vacuity*; it follows, that all thoſe ſhaken Particles muſt neceſſarily take up much more room then when they were at reſt, and lay quietly upon each other. And this is further confirmed by a Pot of *boyling Alabaſter*, which will manifeſtly riſe a ſixth or eighth part higher in the Pot, whilſt it is boyling, then it will remain at, both before and after it be boyled. The reaſon of which odd *Phænomenon* (to hint it here only by the way) is this, that there is in the curious powder of Alabaſter, and other calcining Stones, a certain watery ſubſtance, which is ſo fixt and included with the ſolid Particles, that till the heat be very conſiderable they will not fly away; but after the heat is increaſed to ſuch a degree, they break out every way in vapours, and thereby ſo ſhake and looſen the ſmall corpuſles of the Powder from each other, that they become perfectly of the nature of a fluid body, and one may move a ſtick to and fro through it, and ſtir it as eaſily as water, and the vapours burſt and break out in bubbles juſt as in boyling water, and the like; whereas, both before thoſe watery parts are flying away, and after they are quite gone; that is, before and after it have done boyling, all thoſe effects ceaſe, and a ſtick is as difficultly moved to and fro in it as in ſand, or the like. Which Explication I could eaſily prove, had I time; but this is not a fit place for it.

To proceed therefore, I ſay, that the dropping of this expanded Body into cold Water, does make the parts of the Glaſs ſuffer a double contraction: The firſt is, of thoſe parts which are neer the Surface of the Drop. For Cold, as I ſaid before, contracting Bodies, that is, *by the abatement of the agitating faculty the parts falling neerer together*; the parts next adjoying to the Water muſt needs loſe much of their motion, and impart it to the Ambient-water (which the Ebullition and commotion of it manifeſts) and thereby become a ſolid and hard cruſt, whilſt the innermoſt parts remain yet fluid and expanded; whence, as they grow cold alſo by degrees, their parts muſt neceſſarily be left at liberty to be condenſed, but becauſe of the hardneſs of the outward cruſt, the contraction cannot be admitted that way; but there being many very ſmall, and before inconſpicuous, bubbles in the ſubſtance of the Glaſs, upon the ſubſiding of the parts of the Glaſs, the agil ſubſtance contained in them has liberty of expanding it ſelf a little, and thereby thoſe bubbles grow much bigger, which is the ſecond Contraction. And both theſe are confirmed from the appearance of the Drop it ſelf: for as for the outward parts, we ſee, firſt, that it is irregular and ſhrunk, as it were, which is cauſed by the yielding a little of the hardened Skin to a Contraction, after the very outmoſt Surface is ſettled; and as for the internal parts, one may with ones naked Eye perceive abundance of very conſpicuous bubbles, and with the *Microſcope* many more.

The Conſideration of which Particulars will eaſily make the Third Poſition probable, that is, that the parts of the drop will be of a very hard, though of a rarified Texture; for if the outward parts of the Drop, by reaſon of its hard cruſt, will indure very little Contraction, and the agil Particles, inclu-

ded in thoſe bubbles, by the loſing of their agitation, by thedecreaſe of the Heat,loſe alſo moſt part of their Spring and Expanſive power;it follows (the withdrawing of the heat being very ſudden) that the parts muſt be left in a very looſe Texture, and by reaſon of the implication of the parts one about another,which from their ſluggiſhnes and glutinouſneſs I ſuppoſe to be much after the manner of the ſticks in a Thorn-buſh,or a Lock of Wool;It will follow, I ſay, that the parts will hold each other very ſtrongly together,and indeavour to draw each other neerer together, and conſequently their Texture muſt be very hard and ſtiff, but very much rarified.

And this will make probable my next Poſition, That *the parts of the Glaſs are under a kind of tenſion or flexure,out of which they indeavour to extricate and free themſelves*,and thereby all the parts draw towards the Center or middle, and would, if the outward parts would give way, as they do when the outward parts cool leiſurely (as in baking of Glaſſes) contract the bulk of the drop into a much leſs compaſs. For ſince,as I proved before,the Internal parts of the drop, when fluid,were of a very rarified Texture,and,as it were,tos'd open like a Lock of Wool,and if they were ſuffered leiſurely to cool, would be again preſt, as it were,cloſe together: And ſince that the heat,which kept them bended and open, is removed, and yet the parts not ſuffered to get as neer together as they naturally would; It follows,that the Particles remain under a kind of *tenſion* and *flexure*, and conſequently have an indeavour to free themſelves from that *bending* and *diſtenſion*, which they do, as ſoon as either the tip be broken, or as ſoon as by a leiſurely heating and cooling, the parts are nealed into another poſture.

And this will make my next Poſition probable,that *the parts of the Glaſs drops are contignated together in the form of an Arch*,and cannot any where yield or be drawn inwards,till by the removing of ſome one part of it(as it happens in the removing one of the ſtones of an Arch)the whole Fabrick is ſhatter'd,and falls to pieces,and each of the Springs is left at liberty,ſuddenly to extricate it ſelf: for ſince I have made it probable,that the internal parts of the Glaſs have a contractive power inwards, and the external parts are incapable of ſuch a Contraction,and the figure of it being ſpherical;it follows,that the ſuperficial parts muſt bear againſt each other, and keep one another from being condens'd into a leſs room, in the ſame manner as the ſtones of an Arch conduce to the upholding each other in that Figure.And this is made more probable by another Experiment which was communicated to me by an excellent Perſon,whoſe extraordinary Abilities in all kind of Knowledg, eſpecially in that of Natural things,and his generous Diſpoſition in communicating,incouraged me to have recourſe to him on many occaſions. The Experiment was this: Small Glaſs-balls (about the bigneſs of that repreſented in the *Figure &c.*) would,upon rubbing or ſcratching the inward Surface, fly all inſunder, with a pretty brisk noiſe; whereas neither before nor after the inner Surface had been thus ſcratcht, did there appear any flaw or crack. And putting the pieces of one of thoſe broken ones together again, the flaws appeared much after the manner of the black lines on the Figure, &c. Theſe Balls were ſmall, but exceeding thick bubbles of Glaſs, which being crack'd off from the *Puntilion* whilſt very hot, and ſo ſuffered to cool without nealing them in the

the Oven over the Furnace, do thereby (being made of white Glaſs, which cools much quicker then green Glaſs, and is thereby made much brittler) acquire a very *porous* and very brittle *texture*: ſo that if with the point of a Needle or Bodkin, the inſide of any of them be rubbed prety hard, and then laid on a Table, it will, within a very little while, break into many pieces with a brisk noiſe, and throw the parts above a ſpan aſunder on the Table: Now though the pieces are not ſo ſmall as thoſe of a *fulminating* drop, yet they as plainly ſhew, that the outward parts of the Glaſs have a great *Conatus* to fly aſunder, were they not held together by the *tenacity* of the parts of the inward Surface: for we ſee as ſoon as thoſe parts are crazed by hard rubbing, and thereby their tenacity ſpoiled, the ſpringineſs of the more outward parts quickly makes a divulſion, and the broken pieces will, if the concave Surface of them be further ſcratcht with a Diamond, fly again into ſmaller pieces.

From which preceding conſiderations it will follow Sixthly, That the ſudden flying aſunder of the parts as ſoon as this Arch is any where diſordered or broken, proceeds from the ſpringing of the parts; which, indeavouring to *extricate* themſelves as ſoon as they get the liberty, they perform it with ſuch a quickneſs, that they throw one another away with very great violence: for the Particles that compoſe the Cruſt have a *Conatus* to lye further from one another, and therefore as ſoon as the external parts are looſened they dart themſelves outward with great violence, juſt as ſo many Springs would do, if they were detained and faſtened to the body, as ſoon as they ſhould be ſuddenly looſened; and the internal parts drawing inward, they contract ſo violently, that they rebound back again and fly into multitude of ſmall ſhivers or ſands. Now though they appear not, either to the naked Eye, or the *Microſcope*, yet I am very apt to think there may be abundance of ſmall flaws or cracks, which, by reaſon the ſtrong reflecting Air is not got between the *contiguous* parts, appear not. And that this may be ſo, I argue from this, that I have very often been able to make a crack or flaw, in ſome convenient pieces of Glaſs, to appear and diſappear at pleaſure, according as by preſſing together, or pulling aſunder the contiguous parts, I excluded or admitted the ſtrong reflecting Air between the parts: And it is very probable, that there may be ſome Body, that is either very rarified Air, or ſomething *analogous* to it, which fills the bubbles of theſe drops; which I argue, firſt, from the roundneſs of them, and next, from the vivid reflection of Light which they exhibite: Now though I doubt not, but that the Air in them is very much rarified, yet that there is ſome in them, to ſuch as well conſider this Experiment of the diſappearing of a crack upon the *extruding* of the Air, I ſuppoſe it will ſeem more then probable.

The Seventh and laſt therefore that I ſhall prove, is, *That the gradual heating and cooling of theſe ſo extended bodies does reduce the parts of the Glaſs to a looſer and ſofter temper.* And this I found by heating them, and keeping them for a prety while very red hot in a fire; for thereby I found them to grow a little lighter, and the ſmall Stems to be very eaſily broken and ſnapt any where, without at all making the drop fly; whereas

before they were ſo exceeding hard,that they could not be broken without much difficulty; and upon their breaking the whole drop would fly in pieces with very great violence. The Reaſon of which laſt ſeems to be, that the leiſurely heating and cooling of the parts does not only waſt ſome part of the Glaſs it ſelf, but ranges all the parts into a better order, and gives each Particle an opportunity of *relaxing* its ſelf, and conſequently neither will the parts hold ſo ſtrongly together as before, nor be ſo difficult to be broken: The parts now more eaſily yielding, nor will the other parts fly in pieces, becauſe the parts have no bended Springs. The *relaxation* alſo in the temper of hardned Steel, and hammered Metals by nealing them in the fire,ſeems to proceed from much the ſame cauſe. For both by quenching ſuddenly ſuch Metals as have *vitrified* parts interſpers'd, as Steel has,and by hammering of other kinds that do not ſo much abound with them, as Silver, Braſs, *&c.* the parts are put into and detained in a bended poſture, which by the agitation of Heat are ſhaken, and looſened, and ſuffered to unbend themſelves.

Obſerv. VIII. *Of the fiery Sparks ſtruck from a Flint or Steel.*

Schem. 5. IT is a very common Experiment, by ſtriking with a Flint againſt a Steel,to make certain fiery and ſhining Sparks to fly out from between thoſe two compreſſing Bodies. About eight years ſince, upon caſually reading the Explication of this odd *Phænomenon*, by the moſt Ingenious *Des Cartes*, I had a great deſire to be ſatisfied, what that Subſtance was that gave ſuch a ſhining and bright Light: And to that end I ſpread a ſheet of white Paper,and on it, obſerving the place where ſeveral of theſe Sparks ſeemed to vaniſh, I found certain very ſmall, black, but gliſtering Spots of a movable Subſtance, each of which examining with my *Miſcroſcope*,I found to be a ſmall round *Globule*; ſome of which, as they looked prety ſmall, ſo did they from their Surface yield a very bright and ſtrong reflection on that ſide which was next the Light; and each look'd almoſt like a prety bright Iron-Ball, whoſe Surface was prety regular, ſuch as is repreſented by the Figure A. In this I could perceive the Image of the Window prety well, or of a Stick, which I moved up and down between the Light and it. Others I found,which were, as to the bulk of the Ball, prety regularly round,but the Surface of them,as it was not very ſmooth, but rough,and more irregular, ſo was the reflection from it more faint and confuſed. Such were the Surfaces of B. C. D. and E. Some of theſe I found cleft or cracked, as C, others quite broken in two and hollow, as D. which ſeemed to be half the hollow ſhell of a Granado, broken irregularly in pieces. Several others I found of other ſhapes; but that which is repreſented by E, I obſerved to be a very big Spark of Fire, which went out upon one ſide of the Flint that I ſtruck fire withall, to

which it ſtuck by the root F, at the end of which ſmall Stem was faſten-ed-on a *Hemiſphere*, or half a hollow Ball,with the mouth of it open from the ſtemwards, ſo that it looked much like a Funnel, or an old faſhioned Bowl without a foot. This night, making many tryals and obſervations of this Experiment,I met,among a multitude of the Globular ones which I had obſerved, a couple of Inſtances, which are very remarkable to the confirmation of my *Hypotheſis*.

And the Firſt was of a pretty big Ball faſtened on to the end of a ſmall ſliver of Iron,which *Compoſitum* ſeemed to be nothing elſe but a long thin chip of Iron,one of whoſe ends was melted into a ſmall round Globul;the other end remaining unmelted and irregular, and perfectly Iron.

The Second Inſtance was not leſs remarkable then the Firſt; for I found, when a Spark went out, nothing but a very ſmall thin long ſliver of Iron or Steel, unmelted at either end. So that it ſeems, that ſome of theſe Sparks are the ſlivers or chips of the Iron *vitrified*, Others are only the ſlivers melted into Balls without vitrification, And the third kind are only ſmall ſlivers of the Iron, made red-hot with the violence of the ſtroke given on the Steel by the Flint.

He that ſhall diligently examine the *Phænomena* of this Experiment, will, I doubt not, find cauſe to believe, that the reaſon I have heretofore given of it, is the true and genuine cauſe of it, namely, That *the Spark appearing ſo bright in the falling,is nothing elſe but a ſmall piece of the Steel or Flint, but moſt commonly of the Steel, which by the violence of the ſtroke is at the ſame time ſever'd and heatt red-hot, and that ſometimes to ſuch a degree, as to make it melt together into a ſmall Globule of Steel; and ſometimes alſo is that heat ſo very intenſe, as further to melt it and vitrifie it: but many times the heat is ſo gentle, as to be able to make the ſliver only red hot, which notwithſtanding falling upon the tinder* (that is only a very curious ſmall Coal made of the ſmall threads of Linnen burnt to coals and char'd) *it eaſily ſets it on fire.* Nor will any part of this *Hypotheſis* ſeem ſtrange to him that conſiders, Firſt, that either hammering, or filing or otherwiſe violently rubbing of Steel, will preſently make it ſo hot as to be able to burn ones fingers. Next, that the whole force of the ſtroke is exerted upon that ſmall part where the Flint and Steel firſt touch: For the Bodies being each of them ſo very hard, the puls cannot be far communicated, that is, the parts of each can yield but very little, and therefore the violence of the concuſſion will be *exerted* on that piece of Steel which is cut off by the Flint. Thirdly, that the filings or ſmall parts of Steel are very apt,as it were,to take fire, and are preſently red hot, that is,there ſeems to be a very *combuſtible ſulphureous* Body in Iron or Steel, which the Air very readily preys upon, as ſoon as the body is a little violently heated.

And this is obvious in the filings of Steel or Iron caſt through the flame of a Candle; for even by that ſudden *tranſitus* of the ſmall chips of Iron, they are heat red hot, and that *combuſtible ſulphureous* Body is preſently prey'd upon and devoured by the *aereal* incompaſſing *Menſtruum*, whoſe office in this Particular I have ſhewn in the Explication of Charcole.

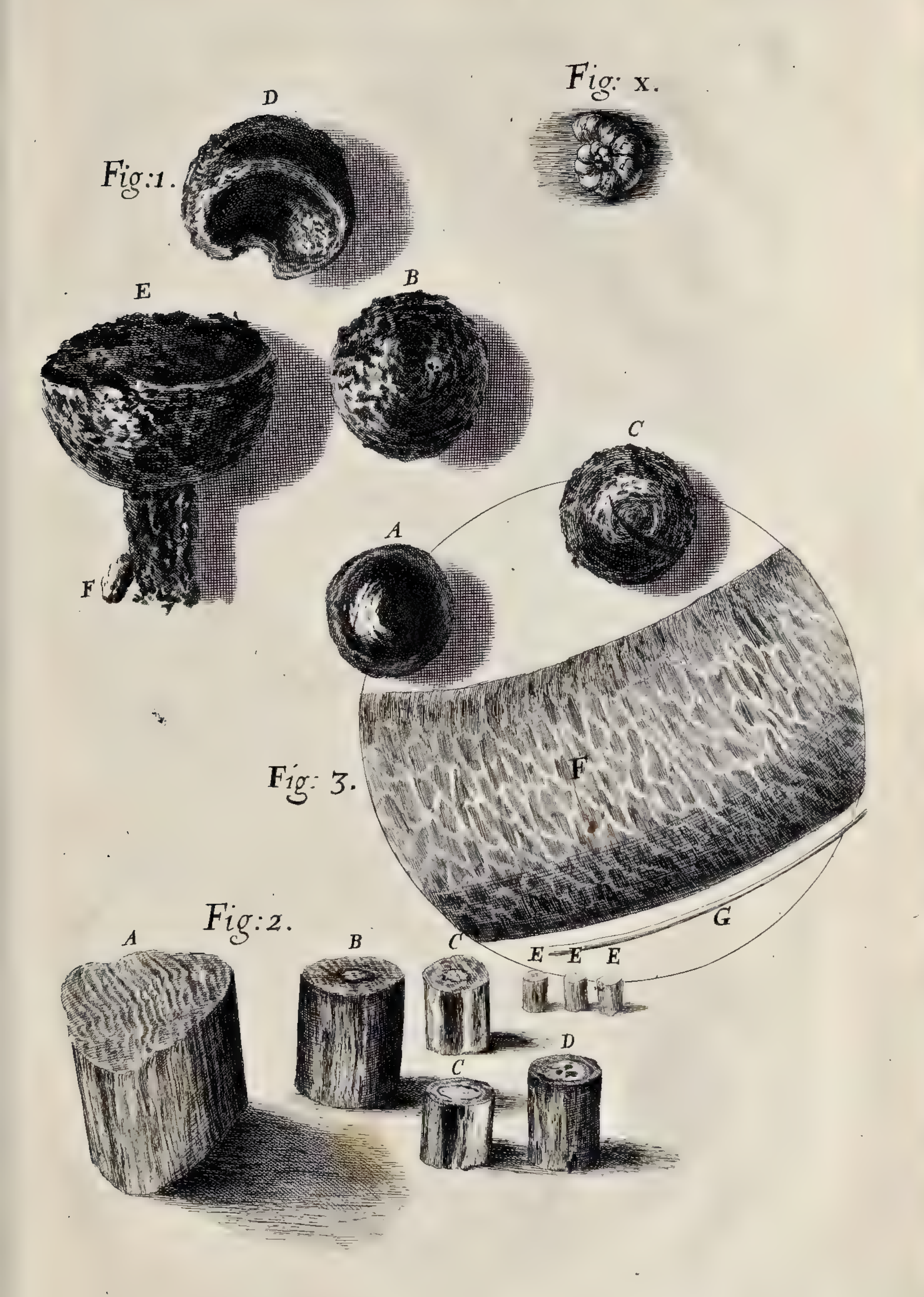
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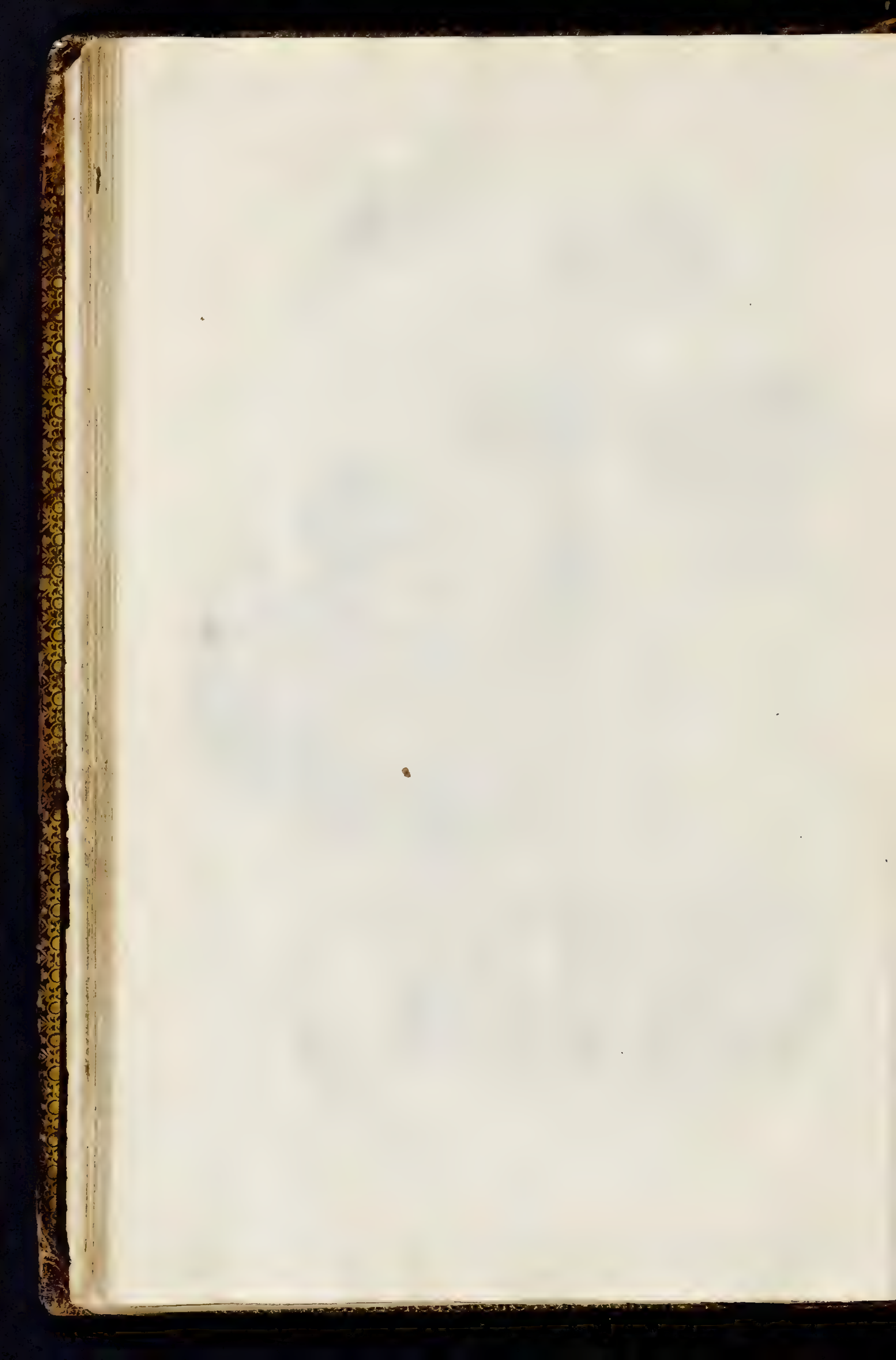
And in profecution of this Experiment,having taken the filings of Iron and Steel, and with the point of a Knife caſt them through the flame of a Candle, I obſerved where ſome conſpicuous ſhining Particles fell, and looking on them with my *Microſcope*, I found them to be nothing elſe but ſuch round Globules, as I formerly found the Sparks ſtruck from the Steel by a ſtroke to be, only a little bigger; and ſhaking together all the filings that had fallen upon the ſheet of Paper underneath, and obſerving them with the *Microſcope*, I found a great number of ſmall Globules, ſuch as the former, though there were alſo many of the parts that had remained untoucht, and rough filings or chips of Iron. So that, it ſeems, Iron does contain a very *combuſtible ſulphureous* Body, which is, in all likelihood, one of the cauſes of this *Phænomenon*, and which may be perhaps very much concerned in the buſineſs of its hardening and tempering: of which ſomewhat is ſaid in the Deſcription of *Muſcovy-glaſs*.

So that, theſe things conſidered, we need not trouble our ſelves to find out what kind of Pores they are, both in the Flint and Steel, that contain the *Atoms of fire*, nor how thoſe *Atoms* come to be hindred from running all out, when a dore or paſſage in their Pores is made by the concuſſion: nor need we trouble our ſelves to examine by what *Prometheus* the Element of Fire comes to be fetcht down from above the Regions of the Air, in what Cells or Boxes it is kept, and what *Epimetheus* lets it go: Nor to conſider what it is that cauſes ſo great a conflux of the atomical Particles of Fire,which are ſaid to fly to a flaming Body, like Vultures or Eagles to a putrifying Carcaſs, and there to make a very great pudder. Since we have nothing more difficult in this *Hypotheſis* to conceive, firſt, as to the kindling of Tinder, then how a large Iron-bullet, let fall red or glowing hot upon a heap of Small-coal, ſhould ſet fire to thoſe that are next to it firſt: Nor ſecondly, is this laſt more difficult to be explicated, then that a Body, as Silver for Inſtance, put into a weak *Menſtruum*, as unrectified *Aqua fortis* ſhould, when it is put in a great heat, be there diſſolved by it, and not before; which *Hypotheſis* is more largely explicated in the Deſcription of Charcoal. To conclude, we ſee by this Inſtance, how much Experiments may conduce to the regulating of *Philoſophical notions*. For if the moſt Acute *Des Cartes* had applied himſelf experimentally to have examined what ſubſtance it was that cauſed that ſhining of the falling Sparks ſtruck from a Flint and a Steel, he would certainly have a little altered his *Hypotheſis*, and we ſhould have found, that his Ingenious Principles would have admitted a very plauſible Explication of this *Phænomenon*; whereas by not examining ſo far as he might, he has ſet down an Explication which Experiment do's contradict.

But before I leave this Deſcription, I muſt not forget to take notice of the Globular form into which each of theſe is moſt curiouſly formed. And this *Phænomenon*, as I have elſewhere more largely ſhewn, proceeds from a propriety which belongs to all kinds of fluid Bodies more or leſs,and is cauſed by the Incongruity of the Ambient and included Fluid, which ſo acts and modulates each other, that they acquire, as neer as is poſſible,

Schem: V





possible, a *sperical* or *globular* form, which propriety and several of the *Phænomena* that proceed from it, I have more fully explicated in the sixth Observation.

One Experiment, which does very much illustrate my present Explication, and is in it self exeeding pretty, I must not pass by: And that is a way of making small *Globules* or *Balls* of Lead, or Tin, as small almost as these of Iron or Steel, and that exceeding easily and quickly, by turning the filings or chips of those Metals also into perfectly round *Globules*. The way, in short, as I received it from the *Learned Physitian Doctor* I. G. is this;

Reduce the Metal you would thus shape, into exceeding fine filings, the finer the filings are, the finer will the Balls be: *Stratifie* these filings with the fine and well dryed powder of quick Lime in a *Crucible* proportioned to the quantity you intend to make: When you have thus filled your *Crucible*, by continual *stratifications* of the filings and powder, so that, as neer as may be, no one of the filings may touch another, place the *Crucible* in a *gradual fire*, and by degrees let it be brought to a heat big enough to make all the filings, that are mixt with the quick Lime, to melt, and no more; for if the fire be too hot, many of these filings will joyn and run together; whereas if the heat be proportioned, upon washing the Lime-dust in fair Water, all those small filings of the Metal will subside to the bottom in a most curious powder, consisting all of exactly round *Globules*, which, if it be very fine, is very excellent to make Hour-glasses of.

Now though quick Lime be the powder that this direction makes choice of, yet I doubt not, but that there may be much more convenient ones found out, one of which I have made tryal of, and found very effectual; and were it not for discovering, by the mentioning of it, another Secret, which I am not free to impart, I should have here inserted it.

Observ. IX. *Of the Colours observable in Muscovy Glass, and other thin Bodies.*

MOscovy-glass, or *Lapis specularis*, is a Body that seems to have as many Curiosities in its Fabrick as any common Mineral I have met with: for first, It is transparent to a great thickness: Next, it is compounded of an infinite number of thin flakes joyned or generated one upon another so close & smooth, as with many hundreds of them to make one smooth and thin Plate of a transparent flexible substance, which with care and diligence may be slit into pieces so exceedingly thin as to be hardly perceivable by the eye, and yet even those, which I have thought the thinnest, I have with a good *Microscope* found to be made up of many other Plates, yet thinner; and it is probable, that, were our *Microscopes*

much

much better, we might much further difcover its divifibility. Nor are thefe flakes only regular as to the fmoothnefs of their Surfaces; but thirdly, In many Plates they may be perceived to be terminated naturally with edges of the figure of a *Rhomboeid*. This Figure is much more confpicuous in our Englifh talk, much whereof is found in the Lead Mines, and is commonly called *Spar*, and *Kauck*, which is of the fame kind of fubftance with the *Selenitis*, but is feldom found in fo large flakes as that is, nor is it altogether fo tuff, but is much more clear and tranfparent, and much more curioufly fhaped, and yet may be cleft and flak'd like the other *Selenitis*. But fourthly, this ftone has a property, which in refpect of the *Microfcope*, is more notable, and that is, that it exhibits feveral appearances of Colours, both to the naked Eye, but much more confpicuoufly to the *Microfcope*; for the exhibiting of which, I took a piece of *Mufcovy-glafs*, and fplitting or cleaving it into thin Plates, I found that up and down in feveral parts of them I could plainly perceive feveral white fpecks or flaws, and others diverfly coloured with all the Colours of the *Rainbow*; and with the *Microfcope* I could perceive, that thefe Colours were ranged in rings that incompaffed the white fpeck or flaw, and were round or irregular, according to the fhape of the fpot which they terminated; and the pofition of Colours, in refpect of one another, was the very fame as in the *Rainbow*. The confecution of thofe Colours from the middle of the fpot outward being Blew, Purple, Scarlet, Yellow, Green; Blew, Purple, Scarlet, and fo onwards, fometimes half a fcore times repeated, that is, there appeared fix, feven, eight, nine or ten feveral coloured rings or lines, each incircling the other, in the fame manner as I have often feen a very *vivid Rainbow* to have four or five feveral Rings of Colours, that is, accounting all the Gradations between Red and Blew for one: But the order of the Colours in thefe Rings was quite contrary to the primary or innermoft *Rainbow*, and the fame with thofe of the fecondary or outermoft Rainbow; thefe coloured Lines or *Irifes*, as I may fo call them, were fome of them much brighter then others, and fome of them alfo very much broader, they being fome of them ten, twenty, nay, I believe, neer a hundred times broader then others; and thofe ufually were broadifh which were neereft the center or middle of the flaw. And oftentimes I found, that thefe Colours reacht to the very middle of the flaw, and then there appeared in the middle a very large fpot, for the moft part, all of one colour, which was very vivid, and all the other Colours incompaffing it, gradually afcending, and growing narrower towards the edges, keeping the fame order, as in the *fecundary Rainbow*, that is, if the middle were Blew, the next incompaffing it would be a Purple, the third a Red, the fourth a Yellow, *&c.* as above; if the middle were a Red, the next without it would be a Yellow, the third a Green, the fourth a Blew, and fo onward. And this order it alwayes kept whatfoever were the middle Colour.

There was further obfervable in feveral other parts of this Body, many Lines or Threads, each of them of fome one peculiar Colour, and thofe fo exceedingly bright and vivid, that it afforded a very pleafant object

through

through the *Microſcope*. Some of theſe *threads* I have obſerved alſo to be pieced or made up of ſeveral ſhort lengths of differently coloured *ends* (as I may ſo call them) as a line appearing about two inches long through the *Microſcope* , has been compounded of about half an inch of a Peach colour, $\frac{1}{8}$ of a lovely Graſs-green, $\frac{1}{4}$ of an inch more of a bright Scarlet,and the reſt of the line of a Watchet blew. Others of them were much otherwiſe coloured; the variety being almoſt infinite. Another thing which is very obſervable, is, that if you find any place where the colours are very broad and conſpicuous to the naked eye, you may, by preſſing that place with your finger, make the colours change places,and go from one part to another.

There is one *Phænomenon* more, which may, if care be uſed, exhibit to the beholder, as it has divers times to me, an exceeding pleaſant, and not leſs inſtructive Spectacle ; And that is, if curioſity and diligence be uſed , you may ſo ſplit this admirable Subſtance , that you may have pretty large Plates (in compariſon of thoſe ſmaller ones which you may obſerve in the Rings) that are perhaps an $\frac{1}{8}$ or a $\frac{1}{6}$ part of an inch over, each of them appearing through the *Microſcope* moſt curiouſly, intirely, and uniformly adorned with ſome one vivid colour : this, if examined with the *Microſcope* , may be plainly perceived to be in all parts of it equally thick. Two, three, or more of theſe lying one upon another, exhibit oftentimes curious compounded colours , which produce ſuch a *Compoſitum* , as one would ſcarce imagine ſhould be the reſult of ſuch *ingredients* : As perhaps a *faint yellow* and a *blew* may produce a very *deep purple*. But when anon we come to the more ſtrict examination of theſe *Phænomena*, and to inquire into the cauſes and reaſons of theſe productions,we ſhall,I hope , make it more conceivable how they are produced, and ſhew them to be no other then the natural and neceſſary effects ariſing from the peculiar union of concurrent cauſes.

Theſe *Phænomena* being ſo various, and ſo truly admirable, it will certainly be very well worth our inquiry , to examine the cauſes and reaſons of them,and to conſider, whether from theſe cauſes demonſtratively evidenced , may not be deduced the true cauſes of the production of all kind of Colours. And I the rather now do it , inſtead of an Appendix or Digreſſion to this Hiſtory, then upon the occaſion of examining the Colours in Peacocks, or other Feathers, becauſe this Subject , as it does afford more variety of particular Colours , ſo does it afford much better wayes of examining each circumſtance. And this will be made manifeſt to him that conſiders , firſt , that this laminated body is more ſimple and regular then the parts of Peacocks feathers, this conſiſting only of an indefinite number of plain and ſmooth Plates, heaped up, or *incumbent* on each other. Next, that the parts of this body are much more manageable, to be divided or joyned, then the parts of a Peacocks feather,or any other ſubſtance that I know. And thirdly, becauſe that in this we are able from a colourleſs body to produce ſeveral coloured bodies, affording all the variety of Colours imaginable : And ſeveral others, which the ſubſequent Inquiry will make manifeſt.

To begin therefore, it is manifeſt from ſeveral circumſtances, that the material cauſe of the *apparition* of theſe ſeveral Colours, is ſome *Lamina* or Plate of a tranſparent or pellucid body of a thickneſs very determinate and proportioned according to the greater or leſs refractive power of the *pellucid* body. And that this is ſo, abundance of Inſtances and particular Circumſtances will make manifeſt.

As *firſt*, if you take any ſmall piece of the *Muſcovy-glaſs*, and with a Needle, or ſome other convenient Inſtrument, cleave it oftentimes into thinner and thinner *Laminæ*, you ſhall find, that till you come to a determinate thinneſs of them, they ſhall all appear tranſparent and colourleſs, but if you continue to ſplit and divide them further, you ſhall find at laſt, that each Plate, after it comes to ſuch a determinate thickneſs, ſhall appear moſt lovely ting'd or imbued with a determinate colour. If *further*, by any means you ſo flaw a pretty thick piece, that one part does begin to cleave a little from the other, and between thoſe two there be by any means gotten ſome pellucid *medium*, thoſe *laminated* pellucid bodies that fill that ſpace, ſhall exhibit ſeveral Rainbows or coloured Lines, the colours of which will be diſpoſed and ranged according to the various thickneſſes of the ſeveral parts of that Plate. That this is ſo, is yet *further* confirmed by this Experiment.

Take two ſmall pieces of ground and poliſht Looking-glaſs-plate, each about the bigneſs of a ſhilling, take theſe two dry, and with your fore-fingers and thumbs preſs them very hard and cloſe together, and you ſhall find, that when they approach each other very near, there will appear ſeveral *Iriſes* or coloured Lines, in the ſame manner almoſt as in the *Muſcovy-glaſs*; and you may very eaſily change any of the Colours of any part of the interpoſed body, by preſſing the Plates cloſer and harder together, or leaving them more lax; that is, a part which appeared coloured with a red, may be preſently ting'd with a yellow, blew, green, purple, or the like, by altering the appropinquation of the terminating Plates. Now that air is not neceſſary to be the interpoſed body, but that any other tranſparent fluid will do much the ſame, may be tryed by wetting thoſe approximated Surfaces with Water, or any other tranſparent Liquor, and proceeding with it in the ſame manner as you did with the Air; and you will find much the like effect, only with this difference, that thoſe compreſt bodies, which differ moſt, in their refractive quality, from the compreſſing bodies, exhibit the moſt ſtrong and vivid tinctures. Nor is it neceſſary, that this *laminated* and *ting'd* body ſhould be of a fluid ſubſtance, any other ſubſtance, provided it be thin enough and tranſparent, doing the ſame thing: this the *Laminæ* of our *Muſcovy-glaſs* hint; but it may be confirm'd by multitudes of other Inſtances.

And firſt, we ſhall find, that even Glaſs it ſelf may, by the help of a Lamp, be blown thin enough to produce theſe *Phænomena* of Colours: which *Phænomena* accidentally happening, as I have been attempting to frame ſmall Glaſſes with a Lamp, did not a little ſurprize me at firſt, having never heard or ſeen any thing of it before; though afterwards comparing it with the *Phænomena*, I had often obſerved

obſerved in thoſe Bubbles which Children uſe to make with Soap-water, I did the leſs wonder; eſpecially when upon Experiment I found, I was able to produce the ſame *Phænomena* in thin Bubbles made with any other tranſparent Subſtance. Thus have I produced them with Bubbles of *Pitch*, *Roſin*, *Colophony*, *Turpentine*, *Solutions* of ſeveral *Gums*, as *Gum-Arabick* in water; any *glutinous* Liquor, as *Wort*, *Wine*, *Spirit of Wine*, *Oyl of Turpentine*, *Glare of Snails*, &c.

It would be needleſs to enumerate the ſeveral Inſtances; theſe being enough to ſhew the generality or univerſality of this propriety. Only I muſt not omit, that we have inſtances alſo of this kind even in metalline Bodies and animal; for thoſe ſeveral Colours which are obſerved to follow each other upon the poliſht ſurface of hardned Steel, when it is by a ſufficient degree of heat gradually tempered or ſoftened, are produced from nothing elſe but a certain thin *Lamina* of a *vitrum* or *vitrified* part of the Metal, which by that degree of heat, and the concurring action of the ambient Air, is driven out and fixed on the ſurface of the Steel.

And this hints to me a very probable (at leaſt, if not the true) cauſe of the hardning and tempering of Steel, which has not, I think, been yet given, nor, that I know of, been ſo much as thought of by any. And that is this, that the hardneſs of it ariſes from a greater proportion of a vitrified Subſtance interſperſed through the pores of the Steel. And that the tempering or ſoftning of it ariſes from the proportionate or ſmaller parcels of it left within thoſe pores. This will ſeem the more probable; if we conſider theſe Particulars.

Firſt, That the pure parts of Metals are of themſelves very *flexible* and *tuff*; that is, will indure bending and hammering, and yet retain their continuity.

Next, That the Parts of all vitrified Subſtances, as all kinds of Glaſs, the *Scoria* of Metals, *&c.* are very hard, and alſo very brittle, being neither *flexible* nor *malleable*, but may by hammering or beating be broken into ſmall parts or powders.

Thirdly, That all Metals (excepting Gold and Silver, which do not ſo much with the bare fire, unleſs aſſiſted by other ſaline Bodies) do more or leſs *vitrifie* by the ſtrength of fire, that is, are corroded by a ſaline Subſtance, which I elſewhere ſhew to be the true cauſe of fire; and are thereby, as by ſeveral other *Menſtruums*, converted into *Scoria*; And this is called, *calcining* of them, by Chimiſts. Thus Iron and Copper by heating and quenching do turn all of them by degrees into *Scoria*, which are evidently *vitrified* Subſtances, and unite with Glaſs, and are eaſily *fuſible*; and when cold, very hard, and very brittle.

Fourthly, That moſt kind of *Vitrifications* or *Calcinations* are made by Salts, uniting and incorporating with the metalline Particles. Nor do I know any one *calcination* wherein a *Saline* body may not, with very great probability, be ſaid to be an agent or coadjutor.

Fifthly, That Iron is converted into Steel by means of the incorporation of certain ſalts, with which it is kept a certain time in the fire.

Sixthly, That any Iron may, in a very little time, be *caſe hardned*, as the Trades-men call it, by caſing the iron to be hardned with clay, and putting between the clay and iron a good quantity of a mixture of *Urine*, *Soot*, *Sea-ſalt*, and *Horſes hoofs* (all which contein great quantities of Saline bodies) and then putting the caſe into a good ſtrong fire, and keeping it in a conſiderable degree of heat for a good while, and afterwards heating, and quenching or cooling it ſuddenly in cold water.

Seventhly, That all kind of vitrify'd ſubſtances, by being ſuddenly cool'd, become very hard and brittle. And thence ariſes the pretty *Phænomena* of the Glaſs Drops, which I have already further explained in its own place.

Eighthly, That thoſe metals which are not ſo apt to vitrifie, do not acquire any hardneſs by quenching in water, as Silver, Gold, &c.

Theſe conſiderations premis'd, will, I ſuppoſe, make way for the more eaſie reception of this following Explication of the *Phænomena* of hardned and temper'd Steel. That Steel is a ſubſtance made out of Iron, by means of a certain proportionate *Vitrification* of ſeveral parts, which are ſo curiouſly and proportionately mixt with the more tough and unalter'd parts of the Iron, that when by the great heat of the fire this vitrify'd ſubſtance is melted, and conſequently rarify'd, and thereby the pores of the Iron are more open, if then by means of dipping it in cold water it be ſuddenly cold, and the parts hardned, that is, ſtay'd in that ſame degree of *Expanſion* they were in when hot, the parts become very hard and brittle, and that upon the ſame account almoſt as ſmall parcels of glaſs quenched in water grow brittle, which we have already explicated. If after this the piece of Steel be held in ſome convenient heat, till by degrees certain colours appear upon the ſurface of the brightned metal, the very hard and brittle tone of the metal, by degrees relaxes and becomes much more tough and ſoft; namely, the action of the heat does by degrees looſen the parts of the Steel that were before ſtreached or ſet *atilt* as it were, and ſtayed open by each other, whereby they become relaxed and ſet at liberty, whence ſome of the more brittle interjacent parts are thruſt out and melted into a thin skin on the ſurface of the Steel, which from no colour increaſes to a deep Purple, and ſo onward by theſe *gradations* or conſecutions, *White*, *Yellow*, *Orange*, *Minium*, *Scarlet*, *Purple*, *Blew*, *Watchet*, &c. and the parts within are more conveniently, and proportionately mixt; and ſo they gradually ſubſide into a texture which is much better proportion'd and cloſer joyn'd, whence that rigidneſſe of parts ceaſes, and the parts begin to acquire their former *ductilneſs*.

Now, that 'tis nothing but the vitrify'd metal that ſticks upon the ſurface of the colour'd body, is evident from this, that if by any means it be ſcraped and rubb'd off, the metal underneath it is white and clear; and if it be kept longer in the fire, ſo as to increaſe to a conſiderable thickneſs, it may, by blows, be beaten off in flakes. This is further confirm'd by this obſervable, that that Iron or Steel will keep longer from ruſting which is covered with this vitrify'd caſe: Thus alſo Lead will, by degrees, be

all

all turn'd into a litharge; for that colour which covers the top being ſcum'd or ſhov'd aſide, appears to be nothing elſe but a litharge or vitrify'd Lead.

This is obſervable alſo in ſome ſort, on Braſs, Copper, Silver, Gold, Tin, but is moſt conſpicuous in Lead: all thoſe Colours that cover the ſurface of the Metal being nothing elſe, but a very thin vitrifi'd part of the heated Metal.

The other Inſtance we have, is in Animal bodies, as in Pearls, Mother of Pearl-ſhels, Oyſter-ſhels, and almoſt all other kinds of ſtony ſhels whatſoever. This have I alſo ſometimes with pleaſure obſerv'd even in Muſcles and Tendons. Further, if you take any glutinous ſubſtance and run it exceedingly thin upon the ſurface of a ſmooth glaſs or a poliſht metaline body, you ſhall find the like effects produced: and in general, whereſoever you meet with a tranſparent body thin enough, that is terminated by reflecting bodies of differing refractions from it, there will be a production of theſe pleaſing and lovely colours.

Nor is it neceſſary, that the two *terminating* Bodies ſhould be both of the ſame kind, as may appear by the *vitrified Laminæ* on *Steel*, *Lead*, and other Metals, one ſurface of which *Laminæ* is contiguous to the ſurface of the Metal, the other to that of the Air.

Nor is it neceſſary, that theſe colour'd *Laminæ* ſhould be of an even thickneſs, that is, ſhould have their edges and middles of equal thickneſs, as in a Looking-glaſs-plate, which circumſtance is only requiſite to make the Plate appear all of the ſame colour; but they may reſemble a *Lens*, that is, have their middles thicker then their edges; or elſe a *double concave*, that is, be thinner in the middle then at the edges; in both which caſes there will be various coloured rings or lines, with differing conſecutions or orders of Colours; the order of the firſt from the middle outwards being Red, Yellow, Green, Blew, *&c.* And the latter quite contrary.

But further, it is altogether neceſſary, that the Plate, in the places where the Colours appear, ſhould be of a determinate thickneſs: Firſt, It muſt not be more then ſuch a thickneſs, for when the Plate is increaſed to ſuch a thickneſs, the Colours ceaſe; and beſides, I have ſeen in a thin piece of *Muſcovy-glaſs*, where the two ends of two Plates, which appearing both ſingle, exhibited two diſtinct and differing Colours; but in that place where they were united, and conſtituted one double Plate (as I may call it) they appeared tranſparent and colourleſs. Nor, Secondly, may the Plates be *thinner* then ſuch a determinate *cize*; for we alwayes find, that the very outmoſt Rim of theſe flaws is terminated in a white and colourleſs Ring.

Further, in this Production of Colours there is no need of a determinate Light of ſuch a bigneſs and no more, nor of a determinate poſition of that Light, that it ſhould be on this ſide, and not on that ſide; nor of a terminating ſhadow, as in the Priſme, and Rainbow, or Water-ball: for we find, that the Light in the open Air, either in or out of the Sun-beams, and within a Room, either from one or many Windows, produces much

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the ſame effect : only where the Light is brighteſt, there the Colours are moſt *vivid.* So does the light of a Candle, collected by a Glaſs-ball. And further, it is all one whatever ſide of the coloured Rings be towards the light; for the whole Ring keeps its proper Colours from the middle outwards in the ſame order as I before related, without varying at all, upon changing the poſition of the light.

But above all it is moſt obſervable, that here are all kind of Colours generated in a *pellucid* body, where there is properly no ſuch refraction as *Des Cartes* ſuppoſes his *Globules* to acquire a *verticity* by: For in the plain and even Plates it is manifeſt, that the ſecond refraction (according to *Des Cartes* his Principles in the *fifth Section of the eighth Chapter of his Meteors*) does regulate and reſtore the ſuppoſed *turbinated Globules* unto their former uniform motion. This Experiment therefore will prove ſuch a one as our *thrice excellent Verulam* calls *Experimentum Crucis*, ſerving as a Guide or Land-mark, by which to direct our courſe in the ſearch after the true cauſe of Colours. Affording us this particular negative Information, that for the production of Colours there is not neceſſary either a great refraction, as in the Priſme; nor Secondly, a determination of Light and ſhadow, ſuch as is both in the Priſme and Glaſs-ball. Now that we may ſee likewiſe what affirmative and poſitive Inſtruction it yields, it will be neceſſary, to examine it a little more particularly and ſtrictly; which that we may the better do, it will be requiſite to premiſe ſomewhat in general concerning the nature of Light and Refraction.

And firſt for Light, it ſeems very manifeſt, that there is no luminous Body but has the parts of it in motion more or leſs.

Firſt, That all kind of *fiery burning Bodies* have their parts in motion, I think, will be very eaſily granted me. That the *ſpark* ſtruck from a Flint and Steel is in a rapid agitation, I have elſewhere made probable. And that the Parts of *rotten Wood, rotten Fiſh*, and the like, are alſo in motion, I think, will as eaſily be conceded by thoſe, who conſider, that thoſe parts never begin to ſhine till the Bodies be in a ſtate of putrefaction; and that is now generally granted by all, to be cauſed by the motion of the parts of putrifying bodies. That the *Bononian ſtone* ſhines no longer then it is either warmed by the Sun-beams, or by the flame of a Fire or of a Candle, is the general report of thoſe that write of it, and of others that have ſeen it. And that heat argues a motion of the internal parts, is (as I ſaid before) generally granted.

But there is one Inſtance more, which was firſt ſhewn to the *Royal Society* by Mr. *Clayton* a worthy Member thereof, which does make this Aſſertion more evident then all the reſt: And that is, That a *Diamond* being *rub'd, ſtruck*, or *heated* in the dark, ſhines for a pretty while after, ſo long as that motion, which is imparted by any of thoſe Agents, remains (in the ſame manner as a Glaſs, rubb'd, ſtruck, or (by a means which I ſhall elſewhere mention) heated, yields a ſound which laſts as long as the *vibrating* motion of that *ſonorous* body) ſeveral Experiments made on which Stone, are ſince publiſhed in a Diſcourſe of Colours, by the truly honou-

honourable Mr. *Boyle*. What may be ſaid of thoſe *Ignes fatui* that appear in the night, I cannot ſo well affirm, having never had the opportunity to examine them my ſelf, nor to be inform'd by any others that had obſerv'd them: And the relations of them in Authors are ſo imperfect, that nothing can be built on them. But I hope I ſhall be able in another place to make it at leaſt very probable, that there is even in thoſe alſo a Motion which cauſes this effect. That the ſhining of *Sea-water* proceeds from the ſame cauſe, may be argued from this, That it ſhines not till either it be beaten againſt a Rock, or be ſome other wayes broken or agitated by Storms, or Oars, or other *percuſſing* bodies. And that the Animal *Energyes* or Spirituous *agil* parts are very active in *Cats eyes* when they ſhine, ſeems evident enough, becauſe their eyes never ſhine but when they look very intenſly either to find their prey, or being hunted in a dark room, when they ſeek after their adverſary, or to find a way to eſcape. And the like may be ſaid of the ſhining *Bellies of Gloworms*, ſince 'tis evident they can at pleaſure either increaſe or extinguiſh that Radiation.

It would be ſomewhat too long a work for this place *Zetetically* to examine, and poſitively to prove, what particular kind of motion it is that muſt be the efficient of Light; for though it be a motion, yet 'tis not every motion that produces it, ſince we find there are many bodies very violently mov'd, which yet afford not ſuch an effect; and there are other bodies, which to our other ſenſes, ſeem not mov'd ſo much, which yet ſhine. Thus Water and quick-ſilver, and moſt other liquors heated, ſhine not; and ſeveral hard bodies, as Iron, Silver, Braſs, Copper, Wood, *&c.* though very often ſtruck with a hammer, ſhine not preſently, though they will all of them grow exceeding hot; whereas rotten Wood, rotten Fiſh, Sea water, Gloworms, *&c.* have nothing of tangible heat in them, and yet (where there is no ſtronger light to affect the Senſory) they ſhine ſome of them ſo Vividly, that one may make a ſhift to read by them.

It would be too long, I ſay, here to inſert the diſcurſive progreſs by which I inquir'd after the proprieties of the motion of Light, and therefore I ſhall only add the reſult.

And, Firſt, I found it ought to be exceeding *quick*, ſuch as thoſe motions of *fermentation* and *putrefaction*, whereby, certainly, the parts are exceeding nimbly and violently mov'd; and that, becauſe we find thoſe motions are able more minutely to ſhatter and divide the body, then the moſt violent heats or *menſtruums* we yet know. And that fire is nothing elſe but ſuch a *diſſolution* of the Burning body, made by the moſt *univerſal menſtruum* of all *ſulphureous bodies*, namely, the Air, we ſhall in an other place of this Tractate endeavour to make probable. And that, in all extreamly hot ſhining bodies, there is a very quick motion that cauſes Light, as well as a more robuſt that cauſes Heat, may be argued from the celerity wherewith the bodyes are diſſolv'd.

Next, it muſt be a *Vibrative motion*. And for this the newly mention'd *Diamond* affords us a good argument; ſince if the motion of the parts did

not

not return,the Diamond muſt after many rubbings decay and be waſted: but we have no reaſon to ſuſpect the latter, eſpecially if we conſider the exceeding difficulty that is found in cutting or wearing away a Diamond. And a Circular motion of the parts is much more improbable, ſince, if that were granted,and they be ſuppos'd irregular and Angular parts, I ſee not how the parts of the Diamond ſhould hold ſo firmly together, or remain in the ſame ſenſible dimenſions, which yet they do. Next, if they be *Globular*, and mov'd only with a *turbinated* motion, I know not any cauſe that can impreſs that motion upon the *pellucid medium*, which yet is done. Thirdly, any other *irregular* motion of the parts one amongſt another, muſt neceſſarily make the body of a fluid conſiſtence, from which it is far enough. It muſt therefore be a *Vibrating* motion.

And Thirdly, That it is a very *ſhort vibrating motion*, I think the inſtances drawn from the ſhining of Diamonds will alſo make probable. For a Diamond being the hardeſt body we yet know in the World, and conſequently the leaſt apt to yield or bend, muſt conſequently alſo have its *vibrations* exceeding ſhort.

And theſe, I think, are the three principal proprieties of a motion, requiſite to produce the effect call'd Light in the Object.

The next thing we are to conſider, is the way or manner of the *trajection* of this motion through the interpos'd pellucid body to the eye: And here it will be eaſily granted,

Firſt, That it muſt be a body *ſuſceptible* and *impartible* of this motion that will deſerve the name of a Tranſparent. And next, that the parts of ſuch a body muſt be *Homogeneous*, or of the ſame kind. Thirdly, that the conſtitution and motion of the parts muſt be ſuch, that the appulſe of the luminous body may be communicated or propagated through it to the greateſt imaginable diſtance in the leaſt imaginable time; though I ſee no reaſon to affirm, that it muſt be in an inſtant: For I know not any one Experiment or obſervation that does prove it. And, whereas it may be objected, That we ſee the Sun riſen at the very inſtant when it is above the ſenſible Horizon, and that we ſee a Star hidden by the body of the Moon at the ſame inſtant, when the Star, the Moon, and our Eye are all in the ſame line; and the like Obſervations, or rather ſuppoſitions, may be urg'd. I have this to anſwer, That I can as eaſily deny as they affirm; for I would fain know by what means any one can be aſſured any more of the Affirmative, then I of the Negative. If indeed the propagation were very ſlow, 'tis poſſible ſomething might be diſcovered by Eclypſes of the Moon; but though we ſhould grant the progreſs of the light from the Earth to the Moon, and from the Moon back to the Earth again to be full two Minutes in performing, I know not any poſſible means to diſcover it; nay, there may be ſome inſtances perhaps of Horizontal Eclypſes that may ſeem very much to favour this ſuppoſition of the ſlower progreſſion of Light then moſt imagine. And the like may be ſaid of the Eclypſes of the Sun, &c. But of this only by the by. Fourthly, That the motion is propagated every way through an *Homogeneous*

geneous medium by *direct* or *straight* lines extended every way like Rays from the center of a Sphere. Fifthly, in an *Homogeneous medium* this motion is propagated every way with *equal velocity*, whence necessarily every *pulse* or *vitration* of the luminous body will generate a Sphere, which will continually increase, and grow bigger, just after the same manner (though indefinitely swifter) as the waves or rings on the surface of the water do swell into bigger and bigger circles about a point of it, where, by the sinking of a Stone the motion was begun, whence it necessarily follows, that all the parts of these Spheres undulated through an *Homogeneous medium* cut the Rays at right angles.

But because all transparent *mediums* are not *Homogeneous* to one another, therefore we will next examine how this pulse or motion will be propagated through differingly transparent *mediums*. And here, according to the most acute and excellent Philosopher *Des Cartes*, I suppose the sign of the angle of inclination in the first *medium* to be to the sign of refraction in the second, As the density of the first, to the density of the second. By density, I mean not the density in respect of gravity (with which the refractions or transparency of *mediums* hold no proportion) but in respect onely to the *trajection* of the Rays of light, in which respect they only differ in this; that the one propagates the pulse more easily and weakly, the other more slowly, but more strongly. But as for the pulses themselves, they will by the refraction acquire another propriety, which we shall now endeavour to explicate.

We will suppose therefore in the first Figure A C F D to be a physical Ray, or A B C and D E F to be two Mathematical Rays, *trajected* from a very remote point of a luminous body through an *Homogeneous* transparent *medium* L L L, and D A, E B, F C, to be small portions of the orbicular impulses which must therefore cut the Rays at right angles; these Rays meeting with the plain surface N O of a *medium* that yields an easier *transitus* to the propagation of light, and falling *obliquely* on it, they will in the *medium* M M M be refracted towards the perpendicular of the surface. And because this *medium* is more easily *trajected* then the former by a third, therefore the point C of the orbicular pulse F C will be mov'd to H four spaces in the same time that F the other end of it is mov'd to G three spaces, therefore the whole refracted pulse G H shall be *oblique* to the refracted Rays C H K and G I; and the angle G H C shall be an acute, and so much the more acute by how much the greater the refraction be, then which nothing is more evident, for the sign of the inclination is to be the sign of refraction as G F to T C the distance between the point C and the perpendicular from G on C K, which being as four to three, H C being longer then G F is longer also then T C, therefore the angle G H C is less than G T C. So that henceforth the parts of the pulses G H and I K are mov'd ascew, or cut the Rays at *oblique* angles.

It is not my business in this place to set down the reasons why this or that body should impede the Rays more, others less: as why Water should transmit the Rays more easily, though more weakly than air. Onely thus

much in general I ſhall hint,that I ſuppoſe the *medium* M M M to have leſs of the tranſparent uudulating ſubtile matter, and that matter to be leſs implicated by it, whereas L L L I ſuppoſe to contain a greater quantity of the fluid undulating ſubſtance,and this to be more implicated with the particles of that *medium*.

But to proceed, the ſame kind of *obliquity* of the Pulſes and Rays will happen alſo when the refraction is made out of a more eaſie into a more difficult *mediū*; as by the calculations of G Q & C S R which are refracted from the perpendicular. In both which calculations 'tis *obvious* to obſerve, that always that part of the Ray towards which the refraction is made has the end of the *orbicular pulſe* precedent to that of the other ſide. And always,the oftner the refraction is made the ſame way,Or the greater the ſingle refraction is, the more is this unequal progreſs. So that having found this odd propriety to be an inſeparable concomitant of a refracted Ray, not ſtreightned by a contrary refraction, we will next examine the refractions of the Sun-beams, as they are ſuffer'd onely to paſs through a ſmall paſſage, *obliquely* out of a more difficult,into a more eaſie *medium*.

Let us ſuppoſe therefore A B C in the ſecond Figure to repreſent a large *Chimical Glaſs-body* about two foot long, filled with very fair Water as high as A B, and inclin'd in a convenient poſture with B towards the Sun: Let us further ſuppoſe the top of it to be cover'd with an *opacous* body, all but the hole *a b*, through which the Sun-beams are ſuffer'd to paſs into the Water,and are thereby refracted to *c d e f*,againſt which part, if a Paper be expanded on the outſide, there will appear all the colours of the Rain-bow, that is, there will be generated the two principal colours, *Scarlet* and *Blue*, and all the *intermediate* ones which ariſe from the compoſition and dilutings of theſe two, that is, *c d* ſhall exhibit a *Scarlet*, which toward *d* is diluted into a *Yellow*; this is the refraction of the Ray, *i k*, which comes from the underſide of the Sun; and the Ray *e f* ſhall appear of a deep *Blue*, which is gradually towards *e* diluted into a pale *Watchet-blue*. Between *d* and *e* the two *diluted* colours, *Blue* and *Yellow* are mixt and compounded into a *Green*; and this I imagine to be the reaſon why *Green* is ſo acceptable a colour to the eye, and that either of the two extremes are, if intenſe, rather a little offenſive, namely, the being plac'd in the middle between the two extremes, and compounded out of both thoſe, *diluted* alſo, or ſomewhat qualifi'd, for the *compoſition*, ariſing from the mixture of the two extremes *undiluted*, makes a *Purple*,which though it be a lovely colour,and pretty acceptable to the eye, yet is it nothing comparable to the raviſhing pleaſure with which a curious and well tempered *Green* affects the eye. If removing the Paper, the eye be plac'd againſt *c d*, it will perceive the lower ſide of the Sun (or a Candle at night which is much better, becauſe it offends not the eye, and is more eaſily manageable) to be of a deep *Red*, and if againſt *e f* it will perceive the upper part of the luminous body to be of a deep *Blue*; and theſe colours will appear deeper and deeper, according as the Rays from the luminous body fall more *obliquely* on the ſurface of the Water, and thereby ſuffer a greater refraction, and the

more

more diſtinct, the further *c d e f* is removed from the trajecting hole.

So that upon the whole, we ſhall find that the reaſon of the *Phænomena* ſeems to depend upon the *obliquity* of the *orbicular pulſe*, to the Lines of Radiation, and in particular, that the Ray *c d* which conſtitutes the *Scarlet* has its inner parts, namely thoſe which are next to the middle of the luminous body, precedent to the outermoſt which are contiguous to the dark and *unradiating* ſkie. And that the Ray *e f* which gives a *Blue*, has its outward part, namely, that which is contiguous to the dark ſkie precedent to the pulſe from the innermoſt, which borders on the bright *area* of the luminous body.

We may obſerve further, that the cauſe of the *diluting* of the colours towards the middle, proceeds partly from the wideneſs of the hole through which the Rays paſs, whereby the Rays from ſeveral parts of the luminous body, fall upon many of the ſame parts between *c* and *f* as is more manifeſt by the Figure: And partly alſo from the nature of the refraction it ſelf, for the vividneſs or ſtrength of the two terminating colours, ariſing chiefly as we have ſeen, from the very great difference that is betwixt the outſides of thoſe *oblique undulations* & the dark Rays circumambient, and that diſparity betwixt the *approximate* Rays, decaying gradually: the further inward toward the middle of the luminous body they are remov'd, the more muſt the colour approach to a white or an undiſturbed light.

Upon the calculation of the refraction and reflection from a Ball of Water or Glaſs, we have much the ſame *Phænomena*, namely, an *obliquity* of the undulation in the ſame manner as we have found it here. Which, becauſe it is very much to our preſent purpoſe, and affords ſuch an *Inſtancia crucis*, as no one that I know has hitherto taken notice of, I ſhall further examine. For it does very plainly and poſitively diſtinguiſh, and ſhew, which of the two *Hypotheſes*, either the *Carteſian* or this is to be followed, by affording a generation of all the colors in the Rainbow, where according to the *Carteſian Principles* there ſhould be none at all generated. And ſecondly, by affording an inſtance that does more cloſely confine the cauſe of theſe *Phænomena* of colours to this preſent *Hypotheſis*.

And firſt, for the *Carteſian*, we have this to object againſt it, That whereas he ſays (*Meteorum Cap.* 8. *Sect.* 5.) *Sed judicabam unicam* (*refractione ſcilicet*) *ad minimũ requiri, & quidem talem ut ejus effectus alia contraria* (*refractione*) *non deſtruatur: Nam experientia docet ſi ſuperficies* NM *&* NP (*nempe refringentes*) *Parallelæ forent, radios tantundem per alteram iterum erectos quantum per unam frangerentur, nullos colores depicturos*; This Principle of his holds true indeed in a priſme where the refracting ſurfaces are plain, but is contradicted by the Ball or Cylinder, whether of Water or Glaſs, where the refracting ſurfaces are Orbicular or Cylindrical. For if we examine the paſſage of any *Globule* or Ray of the primary *Iris*, we ſhall find it to paſs out of the Ball or Cylinder again, with the ſame inclination and refraction that it enter'd in withall, and that that laſt refraction by means of the *intermediate* reflection ſhall be the ſame as if without any reflection at all the Ray had been twice refracted by two Parallel ſurfaces.

And that this is true, not onely in one, but in every Ray that goes to the conſtitution of the Primary Iris; nay, in every Ray, that ſuffers only two refractions, and one reflection, by the ſurface of the round body, we ſhall preſently ſee moſt evident, if we repeat the *Carteſian Scheme*, mentioned in the tenth *Section* of the eighth *Chapter* of his *Meteors*, where E F K N P in the third Figure is one of the Rays of the Primary Iris, twice refracted at F and N, and once reflected at K by the ſurface of the Water-ball. For, firſt it is evident, that K F and K N are equal, becauſe K N being the reflected part of K F they have both the ſame inclination on the ſurface K that is the angles F K T, and N K V made by the two Rays and the Tangent of K are equal, which is evident by the Laws of reflection; whence it will follow alſo, that K N has the ſame inclination on the ſurface N, or the Tangent of it X N that the Ray K F has to the ſurface F, or the Tangent of it F Y, whence it muſt neceſſarily follow, that the refractions at F and N are equal, that is, K F E and K N P are equal. Now, that the ſurface N is by the reflection at K made parallel to the ſurface at F, is evident from the principles of reflection; for reflection being nothing but an inverting of the Rays, if we re-invert the Ray K N P, and make the ſame inclinations below the line T K V that it has above, it will be moſt evident, that K H the inverſe of K N will be the continuation of the line F K, and that L H I the inverſe of O X is parallel to F Y. And H M the inverſe of N P is Parallel to E F for the angle K H I is equal to K N O which is equal to K F Y, and the angle K H M is equal to K N P which is equal to K F E which was to be prov'd.

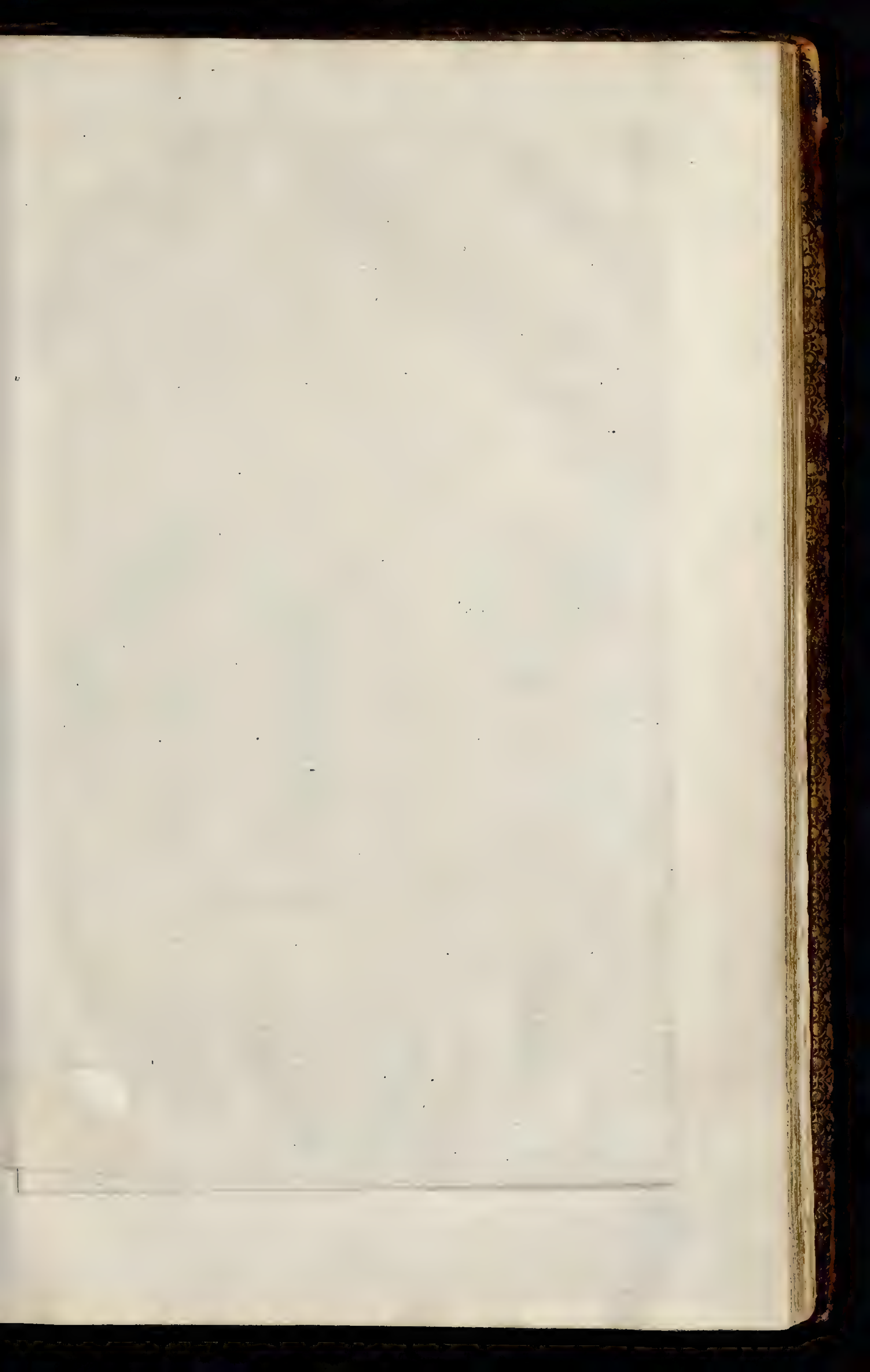
Schem. 6. Fig. 3.

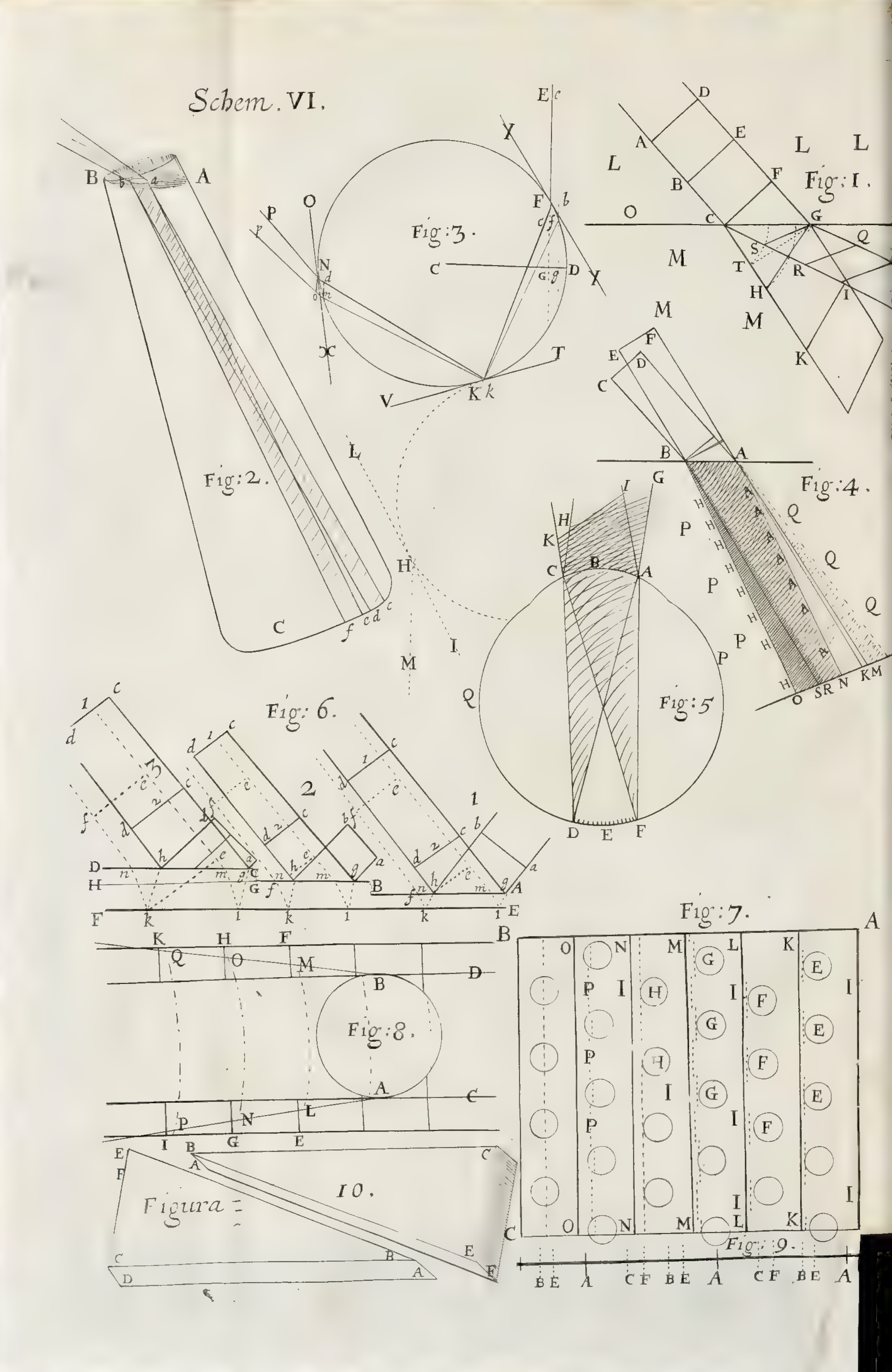
So that according to the above mentioned *Carteſian* principles there ſhould be generated no colour at all in a Ball of Water or Glaſs by two refractions and one reflection, which does hold moſt true indeed, if the ſurfaces be plain, as may be experimented with any kind of priſme where the two refracting ſurfaces are equally inclin'd to the reflecting; but in this the *Phænomena* are quite otherwiſe.

The cauſe therefore of the generation of colour muſt not be what *Des Cartes* aſſigns, namely, a certain *rotation* of the *Globuli ætherei*, which are the particles which he ſuppoſes to conſtitute the *Pellucid medium*, But ſomewhat elſe, perhaps what we have lately ſuppoſed, and ſhall by and by further proſecute and explain.

But, Firſt I ſhall crave leave to propound ſome other difficulties of his, notwithſtanding exceedingly ingenious *Hypotheſis*, which I plainly confeſs to me ſeem ſuch; and thoſe are,

Firſt, if that light be (as is affirmed, *Diopt.* cap. 1. §. 8.) not ſo properly a motion, as an action or propenſion to motion, I cannot conceive how the eye can come to be ſenſible of the *verticity* of a *Globule*, which is generated in a drop of Rain, perhaps a mile off from it. For that *Globule* is not carry'd to the eye according to his formerly recited Principle; and if not ſo, I cannot conceive how it can communicate its *rotation*, or circular motion to the line of the *Globules* between the drop and the eye. It cannot be by means of every ones turning the next before him; for if ſo, then onely all the *Globules* that are in the odd places muſt be turned the ſame way




Schem. VI.
Fig: I.
Fig: 2.
Fig: 3.
Fig: 4.
Fig: 5
Fig: 6.
Fig: 7.
Fig: 8.
Fig: 9.
Figura 10.

way with the first, namely, the 3. 5. 7. 9. 11, *&c.* but all the *Globules* interposited between them in the even places; namely, the 2.4.6.8.10.*&c.* must be the quite contrary; whence, according to the *Cartesian Hypothesis*, there must be no distinct colour generated, but a confusion. Next, since the *Cartesian Globuli* are suppos'd (*Principiorum Philosoph.* Part. 3. §. 86.) to be each of them continually in motion about their centers, I cannot conceive how the eye is able to distinguish this new generated motion from their former inherent one, if I may so call that other wherewith they are mov'd or *turbinated*, from some other cause than refraction. And thirdly, I cannot conceive how these motions should not happen sometimes to oppose each other, and then, in stead of a *rotation*, there would be nothing but a direct motion generated, and consequently no colour. And fourthly, I cannot conceive, how by the *Cartesian Hypothesis* it is possible to give any plausible reason of the nature of the Colours generated in the thin *laminæ* of these our *Microscopical Observations*; for in many of these, the refracting and reflecting surfaces are parallel to each other, and consequently no *rotation* can be generated, nor is there any necessity of a shadow or termination of the bright Rays, such as is suppos'd (*Chap.* 8. §. 5. *Et preterea observavi umbram quoque, aut limitationem luminis requiri*: and *Chap.* 8. §. 9.) to be necessary to the generation of any distinct colours; Besides that, here is oftentimes one colour generated without any of the other appendant ones, which cannot be by the *Cartesian Hypothesis.*

There must be therefore some other propriety of refraction that causes colour. And upon the examination of the thing, I cannot conceive any one more general, inseparable, and sufficient, than that which I have before assign'd. That we may therefore see how exactly our *Hypothesis* agrees also with the *Phænomena* of the refracting round body, whether *Globe* or *Cylinder*, we shall next subjoyn our *Calculation* or *Examen* of it.

And to this end, we will calculate any two Rays: as for instance; let EF be a Ray cutting the *Radius* CD (divided into 20. parts) in G 16. parts distant from C, and *ef* another Ray, which cuts the same *Radius* in *g* 17. parts distant, these will be refracted to K and *k*, and from thence reflected to N and *n*, and from thence refracted toward P and *p*; therefore the Arch F*f* will be 5.[d] 5'. The Arch FK 106.[d] 30'. the Arch *fk* 101.[d] 2'. The line FG 6000. and *fg* 5267. therefore *hf*. 733. therefore F*c* 980, almost. The line FK 16024. and *fk* 15436. therefore N*d* 196. and *no* 147 almost, the line N*n* 1019 the Arch N*n* 5.[d] 51'. therefore the Angle N*no* is 34.[d] 43'. therefore the Angle N*on*. is 139.[d] 56'. which is almost 50.[d] more than a right Angle.

Schem. 6. *Fig.* 3.

It is evident therefore by this *Hypothesis*, that at the same time that *ef* touches *f*. EF is arrived at *c*. And by that time *efkn* is got to *n*, EFKN is got to *d*, and when it touches N, the pulse of the other Ray is got to *o*, and no farther, which is very short of the place it should have arriv'd to, to make the Ray *np* to cut the *orbicular pulse*. N*o* at right Angles: therefore the Angle N*op* is an acute Angle, but the quite contrary

trary of this will happen,if 17.and 18.be calculated in ſtead of 16.and 17. both which does moſt exactly agree with the *Phænomena* : For if the Sun, or a Candle (which is better) be placed about E *e*, and the eye about P *p*, the Rays E F *e f*. at 16. and 17. will paint the ſide of the luminous object toward *n p Blue*,and towards N P *Red*. But the quite contrary will happen when E F is 17. and *e f* 18. for then towards N P ſhall be a *Blue*, and towards *n p* a *Red*, exactly according to the calculation. And there appears the *Blue* of the Rainbow, where the two *Blue* ſides of the two Images unite, and there the *Red* where the two *Red* ſides unite, that is, where the two Images are juſt diſappearing; which is, when the Rays E F and N P produc'd till they meet,make an Angle of about 41. and an half; the like union is there of the two Images in the Production of the *Secundary Iris*, and the ſame cauſes, as upon calculation may appear; onely with this difference, that it is ſomewhat more faint, by reaſon of the duplicate reflection, which does always weaken the impulſe the oftner it is repeated.

Now, though the ſecond refraction made at N *n* be convenient,that is, do make the Rays glance the more, yet is it not altogether requiſite; for it is plain from the calculation, that the pulſe *d n* is ſufficiently *oblique* to the Rays K N and *k n*,as wel as the pulſe *f c* is *oblique* to the Rays F K & *f k*. And therefore if a piece of very fine Paper be held cloſe againſt N *n* and the eye look on it either through the Ball as from D, or from the other ſide, as from B. there ſhall appear a Rainbow, or colour'd line painted on it with the part toward X appearing *Red*, towards O, *Blue*; the ſame alſo ſhall happen, if the Paper be placed about K *k*, for towards T ſhall appear a *Red*, and towards V a *Blue*, which does exactly agree with this my *Hypotheſis*, as upon the calculation of the progreſs of the pulſe will moſt eaſily appear.

Nor do theſe two obſervations of the colours appearing to the eye about *p* differing from what they appear on the Paper at N contradict each other; but rather confirm and exactly agree with one another, as will be evident to him that examines the reaſons ſet down by the ingenious *Des Cartes* in the 12. *Sect.* of the 8. *Chapter of his Meteors*, where he gives the true reaſon why the colours appear of a quite contrary order to the eye, to what they appear'd on the Paper if the eye be plac'd in ſteed of the Paper: And as in the Priſme, ſo alſo in the Water, Drop, or Globe the *Phænomena* and reaſon are much the ſame.

Having therefore ſhewn that there is ſuch a propriety in the *priſme* and water *Globule* whereby the pulſe is made *oblique* to the progreſſive, and that ſo much the more, by how much greater the refraction is, I ſhall in the next place conſider, how this conduces to the production of colours, and what kind of impreſſion it makes upon the bottom of the eye; and to this end it will be requiſite to examine this *Hypotheſis* a little more particularly.

Firſt therefore, if we conſider the manner of the progreſs of the pulſe, it will ſeem rational to conclude, that that part or end of the pulſe which precedes the other,muſt neceſſarily be ſomwhat more *obtunded*,or *impeded*

by

by the resistance of the transparent *medium*, than the other part or end of it which is subsequent, whose way is, as it were, prepared by the other; especially if the adjacent *medium* be not in the same manner enlightned or agitated. And therefore(in the fourth *Figure* of the sixth *Iconism*)the Ray A A A H B will have its side H H more deadned by the resistance of the dark or quiet *medium* P P P, Whence there will be a kind of deadness superinduc'd on the side H H H, which will continually increase from B, and strike deeper and deeper into the Ray by the line B R; Whence all the parts of the triangle, R B H O will be of a dead *Blue* colour, and so much the deeper, by how much the nearer they lie to the line B H H, which is most deaded or impeded, and so much the more *dilute*, by how much the nearer it approaches the line B R. Next on the other side of the Ray A A N, the end A of the pulse A H will be promoted, or made stronger, having its passage already prepar'd as 'twere by the other parts preceding,and so its impression wil be stronger;And because of its *obliquity* to the Ray,there will be propagated a kind of faint motion into Q Q the adjacent dark or quiet *medium*, which faint motion will spread further and further into Q Q as the Ray is propagated further and further from A,namely,as far as the line M A,whence all the triangle M A N will be ting'd with a *Red*, and that *Red* will be the deeper the nearer it approaches the line M A, and the *paler* or *yellower* the nearer it is the line N A. And if the Ray be continued,so that the lines A N and B R (which are the bounds of the *Red* and *Blue diluted*) do meet and cross each other, there will be beyond that intersection generated all kinds of *Greens*.

Now,these being the proprieties of every single refracted Ray of light, it will be easie enough to consider what must be the result of very many such Rays collateral: As if we suppose infinite such Rays *interjacent* between A K S B and A N O B, which are the terminating: For in this case the Ray A K S B will have its *Red* triangle intire,as lying next to the dark or quiet *medium*, but the other side of it B S will have no *Blue*, because the *medium adjacent* to it S B O, is mov'd or enlightned,and consequently that light does destroy the colour. So likewise will the Ray A N O B lose its *Red*,because the *adjacent medium* is mov'd or enlightned,but the other side of the Ray that is *adjacent* to the dark, namely, A H O will preserve its *Blue* entire, and these Rays must be so far produc'd as till A N and B R cut each other, before there will be any *Green* produc'd. From these Proprieties well consider'd, may be deduc'd the reasons of all the *Phænomena* of the *prisme*, and of the *Globules* or drops of Water which conduce to the production of the Rainbow.

Next for the impression they make on the *Retina*, we will further examine this *Hypothesis*: Suppose therefore A B C D E F,in the fifth *Figure*, to represent the Ball of the eye: on the *Cornea* of which A B C two Rays G A C H and K C A I (which are the terminating Rays of a luminous body) falling, are by the refraction thereof collected or *converg'd* into two points at the bottom of the eye. Now, because these terminating Rays, and all the *intermediate* ones which come from any part of the luminous body, are suppos'd by some sufficient refraction before they

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enter the eye, to have their pulses made *oblique* to their progression, and consequently each Ray to have potentially *superinduc'd* two proprieties, or colours, *viz.* a *Red* on the one side, and a *Blue* on the other, which notwithstanding are never actually manifest, but when this or that Ray has the one or the other side of it bordering on a dark or unmov'd *medium*, therefore as soon as these Rays are entred into the eye, and so have one side of each of them bordering on a dark part of the humours of the eye, they will each of them actually exhibit some colour; therefore A D C the production G A C H will exhibit a *Blue*, because the side C D is *adjacent* to the dark *medium* C Q D C, but nothing of a *Red*, because its side A D is *adjacent* to the enlightned *medium* A D F A : And all the Rays that from the points of the luminous body are collected on the parts of the *Retina* between D and F shall have their *Blue* so much the more *diluted* by how much the farther these points of collection are distant from D towards F; and the Ray A F C the production of K C A I, will exhibit a *Red*, because the side A F is adjacent to the dark or quiet *medium* of the eye A P F A, but nothing of a *Blue*, because its side C F is *adjacent* to the enlightned *medium* C F D C, and all the Rays from the intermediate parts of the luminous body that are collected between F and D shall have their *Red* so much the more diluted, by how much the farther they are distant from F towards D.

Now, because by the refraction in the *Cornea*, and some other parts of the eye, the sides of each Ray, which before were almost parallel, are made to *converge* and meet in a point at the bottom of the eye, therefore that side of the *pulse* which preceded before these refractions, shall first touch the *Retina*, and the other side last. And therefore according as this or that side, or end of the pulse shall be impeded, accordingly will the *impressions* on the *Retina* be varied; therefore by the Ray G A C H refracted by the *Cornea* to D there shall be on that point a stroke or impression confus'd, whose weakest end, namely, that by the line C D shall precede, and the stronger, namely, that by the line A D shall follow. And by the Ray K C A I refracted to F, there shall be on that part a confus'd stroke or impression, whose strongest part, namely, that by the line C F shal precede, and whose weakest or impeded, namely, that by the line A F shall follow, and all the intermediate points between F and D will receive impression from the *converg'd* Rays so much the more like the impressions on F and D by how much the nearer they approach that or this.

From the consideration of the proprieties of which impressions, we may collect these short definitions of Colours : That *Blue is an impression on the Retina of an oblique and confus'd pulse of light, whose weakest part precedes, and whose strongest follows.* And, that *Red is an impression on the Retina of an oblique and confus'd pulse of light, whose strongest part precedes, and whose weakest follows.*

Which proprieties, as they have been already manifested, in the Prisme and falling drops of Rain, to be the causes of the colours there generated, may be easily found to be the efficients also of the colours appearing in thin *laminated* transparent bodies; for the explication of which, all this has been premised.

And

And that this is ſo, a little cloſer examination of the *Phænomena* and the *Figure* of the body, by this *Hypotheſis*, will make evident.

For firſt (as we have already obſerved) the *laminated* body muſt be of a determinate thickneſs, that is, it muſt not be thinner then ſuch a determinate quantity; for I have always obſerv'd, that neer the edges of thoſe which are exceeding thin, the colours diſappear, and the part grows white; nor muſt it be thicker then another determinate quantity; for I have likewiſe obſerv'd, that beyond ſuch a thickneſs,no colours appear'd, but the Plate looked white, between which two determinate thickneſſes were all the colour'd Rings; of which in ſome ſubſtances I have found ten or twelve, in others not half ſo many, which I ſuppoſe depends much upon the tranſparency of the *laminated* body. Thus though the conſecutions are the ſame in the ſcumm or the ſkin on the top of metals; yet in thoſe conſecutions the ſame colour is not ſo often repeated as in the conſecutions in thin Glaſs, or in Sope-water, or any other more tranſparent and glutinous liquor; for in theſe I have obſerv'd, *Red*, *Yellow*, *Green*, *Blue*, *Purple*; *Red*,*Yellow*,*Green*,*Blue*, *Purple*; *Red*,*Yellow*,*Green*, *Blue*, *Purple*; *Red*, *Yellow*, &c. to ſucceed each other,ten or twelve times, but in the other more *opacous* bodies the conſecutions will not be half ſo many.

And therefore ſecondly, the *laminated* body muſt be tranſparent, and this I argue from this, that I have not been able to produce any colour at all with an *opacous* body,though never ſo thin. And this I have often try'd, by preſſing a ſmall *Globule* of *Mercury* between two ſmooth Plates of Glaſs, whereby I have reduc'd that body to a much greater thinneſs then was requiſite to exhibit the colours with a tranſparent body.

Thirdly,there muſt be a conſiderable reflecting body adjacent to the under or further ſide of the *lamina* or *plate*: for this I always found,that the greater that reflection was, the more vivid were the appearing colours.

From which Obſervations,it is moſt evident,that the reflection from the under or further ſide of the body is the principal cauſe of the production of theſe colours; which,that it is ſo,and how it conduces to that effect,I ſhall further explain in the following Figure,which is here deſcribed of a very great thickneſs, as if it had been view'd through the *Microſcope*; and 'tis indeed much thicker than any *Microſcope*(I have yet us'd)has been able to ſhew me thoſe colour'd plates of Glaſs, or *Muſcovie-glaſs*, which I have not without much trouble view'd with it; for though I have endeavoured to magnifie them as much as the Glaſſes were capable of, yet are they ſo exceeding thin, that I have not hitherto been able poſitively to determine their thickneſs. This Figure therefore I here repreſent, is wholy *Hypothetical*.

Let ABCDHFE in the ſixth Figure be a *fruſtum* of *Muſcovy-glaſs*, thinner toward the end A E, and thicker towards D F. Let us firſt ſuppoſe the Ray *a g h b* coming from the Sun, or ſome remote luminous object to fall *obliquely* on the thinner plate B A E, part therefore is reflected back, by *c g h d*, the firſt *Superficies*; whereby the perpendicular

L pulſe

pulſe *a b* is after reflection propagated by *c d*, *c d*, equally remote from each other with *a b*, *a b*, ſo that *ag* + *gc*, or *b h* + *h d* are either of them equal to *a a*, as is alſo *c c*, but the body B A E being tranſparent, a part of the light of this Ray is refracted in the ſurface A B, and propagated by *g i k h* to the ſurface E F, whence it is reflected and refracted again by the ſurface A B. So that after two refractions and one reflection, there is propagated a kind of fainter Ray *e m n f*, whoſe pulſe is not onely weaker by reaſon of the two refractions in the ſurface A B, but by reaſon of the time ſpent in paſſing and repaſſing between the two ſurfaces A B and E F, *e f* which is this fainter or weaker pulſe comes behind the pulſe *c d*; ſo that hereby (the ſurfaces A B, and E F being ſo neer together, that the eye cannot *diſcriminate* them from one) this confus'd or *duplicated* pulſe, whoſe ſtrongeſt part precedes, and whoſe weakeſt follows, does produce on the *Retina* (or the *optick nerve* that covers the bottom of the eye) the ſenſation of a *Yellow*.

And ſecondly, this *Yellow* will appear ſo much the deeper, by how much the further back towards the middle between *c d* and *c d* the ſpurious pulſe *e f* is remov'd, as in 2 where the ſurface B C being further remov'd from E F, the weaker pulſe *e f* will be nearer to the middle, and will make an impreſſion on the eye of a *Red*.

But thirdly, if the two reflecting ſurfaces be yet further remov'd aſunder (as in 3 C D and E F are) then will the weaker pulſe be ſo farr behind, that it will be more then half the diſtance between *c d* and *c d*. And in this caſe it will rather ſeem to precede the following ſtronger pulſe, then to follow the preceding one, and conſequently a *Blue* will be generated. And when the weaker pulſe is juſt in the middle beween two ſtrong ones, then is a deep and lovely *Purple* generated; but when the weaker pulſe *e f* is very neer to *c d*, then is there generated a *Green*, which will be *bluer*, or *yellower*, according as the *approximate* weak pulſe does precede or follow the ſtronger.

Now fourthly, if the thicker Plate chance to be cleft into two thinner Plates, as C D F E is divided into two Plates by the ſurface G H then from the compoſition ariſing from the three reflections in the ſurfaces C D, G H, and E F, there will be generated ſeveral compounded or mixt colours, which will be very differing, according as the proportion between the thickneſſes of thoſe two divided Plates C D H G, and G H F E are varied.

And fifthly, if theſe ſurfaces C D and F E are further remov'd aſunder, the weaker pulſe will yet lagg behind much further, and not onely be *coincident* with the ſecond, *c d*, but lagg behind that alſo, and that ſo much the more, by how much the thicker the Plate be; ſo that by degrees it will be *coincident* with the third *c d* backward alſo, and by degrees, as the Plate grows thicker with a fourth, and ſo onward to a fifth, ſixth, ſeventh, or eighth; ſo that if there be a thin tranſparent body, that from the greateſt thinneſs requiſite to produce colours, does, in the manner of a Wedge, by degrees grow to the greateſt thickneſs that a Plate can be of, to exhibit a colour by the reflection of Light from ſuch a body, there

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ſhall be generated ſeveral conſecutions of colours, whoſe order from the thin end towards the thick, ſhall be *Yellow, Red, Purple, Blue, Green*; *Yellow, Red, Purple, Blue, Green*; *Yellow, Red, Purple, Blue, Green*; *Yellow*, &c. and theſe ſo often repeated, as the weaker pulſe does loſe paces with its *Primary*, or firſt pulſe, and is *coincident* with a ſecond, third, fourth, fifth, ſixth, *&c.* pulſe behind the firſt. And this, as it is *coincident*, or follows from the firſt *Hypotheſis* I took of colours, ſo upon exeriment have I found it in multitudes of inſtances that ſeem to prove it. One thing which ſeems of the greateſt concern in this *Hypotheſis*, is to determine the greateſt or leaſt thickneſs requiſite for theſe effects, which, though I have not been wanting in attempting, yet ſo exceeding thin are theſe coloured Plates, and ſo imperfect our *Microſcope*, that I have not been hitherto ſuceeſsfull, though if my endeavours ſhall anſwer my expectations, I ſhall hope to gratifie the curious Reader with ſome things more remov'd beyond our reach hitherto.

Thus have I, with as much brevity as I was able, endeavoured to explicate (*Hypothetically* at leaſt) the cauſes of the *Phænomena* I formerly recited, on the conſideration of which I have been the more particular.

Firſt, becauſe I think theſe I have newly given are capable of explicating all the *Phænomena* of colours, not onely of thoſe appearing in the *Priſme*, Water-drop, or Rainbow, and in *laminated* or plated bodies, but of all that are in the world, whether they be fluid or ſolid bodies, whether in thick or thin, whether tranſparent, or ſeemingly opacous, as I ſhall in the next Obſervation further endeavour to ſhew. And ſecondly, becauſe this being one of the two ornaments of all bodies diſcoverable by the ſight, whether looked on with, or without a *Microſcope*, it ſeem'd to deſerve (ſomewhere in this Tract, which contains a deſcription of the Figure and Colour of ſome minute bodies) to be ſomewhat the more intimately enquir'd into.

Obſerv. X. *Of* Metalline, *and other real Colours.*

HAving in the former Diſcourſe, from the Fundamental cauſe of Colour, made it probable, that there are but two Colours, and ſhewn, that the *Phantaſm* of Colour is caus'd by the ſenſation of the *oblique* or uneven pulſe of Light which is capable of no more varieties than two that ariſe from the two ſides of the *oblique* pulſe, though each of thoſe be capable of infinite gradations or degrees (each of them beginning from *White*, and ending the one in the deepeſt *Scarlet* or *Yellow*, the other in the deepeſt *Blue*) I ſhall in this *Section* ſet down ſome Obſervations which I have made of other colours, ſuch as *Metalline* powders tinging or colour'd bodies and ſeveral kinds of tinctures or ting'd liquors, all which, together with thoſe I treated of in the former Obſervation will, I ſuppoſe, compriſe the ſeveral ſubjects in which colour is obſerv'd to be inherent, and the ſeveral manners by which it *inheres*, or is apparent

in them. And here I shall endeavour to shew by what composition all kind of compound colours are made, and how there is no colour in the world but may be made from the various degrees of these two colours, together with the intermixtures of *Black* and *White*.

And this being so, as I shall anon shew, it seems an evident argument to me, that all colours whatsoever, whether in fluid or solid, whether in very transparent or seemingly *opacous*, have the same efficient cause, to wit, some kind of *refraction* whereby the Rays that proceed from such bodies, have their pulse *obliquated* or confus'd in the manner I explicated in the former *Section*; that is, a *Red* is caus'd by a duplicated or confus'd pulse, whose strongest pulse precedes, and a weaker follows: and a *Blue* is caus'd by a confus'd pulse, where the weaker pulse precedes, and the stronger follows. And according as these are, more or less, or variously mixt and compounded, so are the *sensations*, and consequently the *phantasms* of colours *diversified*.

To proceed therefore; I suppose, that all transparent colour'd bodies, whether fluid or solid, do consist at least of two parts, or two kinds of substances, the one of a substance of a somewhat differing *refraction* from the other. That one of these substances which may be call'd the *tinging* substance, does consist of distinct parts, or particles of a determinate bigness which are *disseminated*, or dispers'd all over the other: That these particles, if the body be equally and uniformly colour'd, are evenly rang'd and dispers'd over the other contiguous body; That where the body is deepest ting'd, there these particles are rang'd thickest; and where 'tis but faintly ting'd, they are rang'd much thinner, but uniformly. That by the mixture of another body that unites with either of these, which has a differing refraction from either of the other, quite differing effects will be produc'd, that is, the *consecutions* of the confus'd pulses will be much of another kind, and consequently produce other *sensations* and *phantasms* of colours, and from a *Red* may turn to a *Blue*, or from a *Blue* to a *Red*, &c.

Now, that this may be the better understood, I shall endeavour to explain my meaning a little more sensible by a *Scheme*: Suppose we therefore in the seventh *Figure* of the sixth *Scheme*, that A B C D represents a Vessel holding a ting'd liquor, let I I I I I, &c. be the clear liquor, and let the tinging body that is mixt with it be E E, *&c.* F F, *&c.* G G, *&c.* H H, *&c.* whose particles (whether round, or some other determinate Figure is little to our purpose) are first of a determinate and equal bulk. Next, they are rang'd into the form of *Quincunx*, or *Equilaterotriangular* order, which that probably they are so, and why they are so, I shall elsewhere endeavour to shew. Thirdly, they are of such a nature, as does either more easily or more difficultly transmit the Rays of light then the liquor; if more easily, a *Blue* is generated, and if more difficultly, a *Red* or *Scarlet*.

And first, let us suppose the tinging particles to be of a substance that does more *impede* the Rays of light, we shall find that the pulse or wave of light mov'd from A D to B C, will proceed on, through the containing *medium* by the pulses or waves K K, L L, M M, N N, O O; but

because

becauſe ſeveral of theſe Rays that go to the conſtitution of theſe pulſes will be ſlugged or ſtopped by the tinging particles E,F,G,H; therefore there ſhall be a *ſecundary* and weak pulſe that ſhall follow the Ray, namely P P which will be the weaker: firſt, becauſe it has ſuffer'd many refractions in the impeding body; next, for that the Rays will be a little diſpers'd or confus'd by reaſon of the refraction in each of the particles, whether *round* or *angular*; and this will be more evident, if we a little more cloſely examine any one particular tinging *Globule*.

Suppoſe we therefore A B in the eighth *Fgure* of the ſixth *Scheme*, to repreſent a tinging *Globule* or particle which has a greater refraction than the liquor in which it is contain'd: Let C D be a part of the pulſe of light which is *propagated* through the containing *medium*; this pulſe will be a little ſtopt or impeded by the *Globule*, and ſo by that time the pulſe is paſt to E F that part of it which has been impeded by paſſing through the *Globule*, will get but to L M, and ſo that pulſe which has been *propagated* through the *Globule*, to wit, L M, N O, P Q, will always come behind the pulſes E F, G H, I K, *&c.*

Next, by reaſon of the greater impediment in A B, and its *Globular* Figure, the Rays that paſs through it will be diſpers'd, and very much ſcatter'd. Whence C A and D B which before went *direct* and *parallel*, will after the refraction in A B, *diverge* and ſpread by A P, and B Q; ſo that as the Rays do meet with more and more of theſe tinging particles in their way, by ſo much the more will the pulſe of light further lagg behind the clearer pulſe, or that which has fewer refractions, and thence the deeper will the colour be, and the fainter the light that is trajected through it; for not onely many Rays are reflected from the ſurfaces of A B, but thoſe Rays that get through it are very much diſordered.

By this *Hypoheſis* there is no one experiment of colour that I have yet met with, but may be, I conceive, very rationably ſolv'd, and perhaps, had I time to examine ſeveral particulars requiſite to the demonſtration of it, I might prove it more than probable, for all the experiments about the changes and mixings of colours related in the Treatiſe of Colours, publiſhed by the *Incomparable* Mr. *Boyle*, and multitudes of others which I have obſerv'd, do ſo eaſily and naturally flow from thoſe principles, that I am very apt to think it probable, that they own their production to no other *ſecundary* cauſe: As to inſtance in two or three experiments. In the twentieth Experiment, this *Noble Authour* has ſhewn that the deep *bluiſh purple-colour* of *Violets*, may be turn'd into a *Green*, by *Alcalizate Salts*, and to a *Red* by *acid*; that is, a *Purple* conſiſts of two colours, a deep *Red*, and a deep *Blue*; when the *Blue* is diluted, or altered, or deſtroy'd by *acid Salts*, the *Red* becomes predominant, but when the *Red* is diluted by *Alcalizate*, and the *Blue* heightned, there is generated a *Green*; for of a *Red* diluted, is made a *Yellow*, and *Yellow* and *Blue* make a *Green*.

Now, becauſe the *ſpurious* pulſes which cauſe a *Red* and a *Blue*, do the one follow the clear pulſe, and the other precede it, it uſually follows, that thoſe *Saline* refracting bodies which do *dilute* the colour of the one, do deepen that of the other. And this will be made manifeſt by almoſt

moſt all kinds of *Purples*, and many ſorts of *Greens*, both theſe colours conſiſting of mixt colours; for if we ſuppoſe A and A in the ninth Figure, to repreſent two pulſes of clear light, which follow each other at a convenient diſtance, A A, each of which has a *ſpurious* pulſe preceding it, as B B, which makes a *Blue*, and another following it, as C C, which makes a *Red*, the one caus'd by tinging particles that have a greater refraction, the other by others that have a leſs refracting quality then the liquor or *Menſtruum* in which theſe are diſſolv'd, whatſoever liquor does ſo alter the refraction of the one, without altering that of the other part of the ting'd liquor, muſt needs very much alter the colour of the liquor; for if the refraction of the *diſſolvent* be increas'd, and the refraction of the tinging particles not altered, then will the preceding *ſpurious* pulſe be ſhortned or ſtopt, and not out-run the clear pulſe ſo much; ſo that B B will become E E, and the *Blue* be *diluted*, whereas the other *ſpurious* pulſe which follows will be made to lagg much more, and be further behind A A than before, and C C will become *f f*, and ſo the *Yellow* or *Red* will be heightned.

A *Saline* liquor therefore, mixt with another ting'd liquor, may alter the colour of it ſeveral ways, either by altering the refraction of the liquor in which the colour ſwims: or ſecondly by varying the refraction of the coloured particles, by uniting more intimately either with ſome particular *corpuſcles* of the tinging body, or with all of them, according as it has a *congruity* to ſome more eſpecially, or to all alike: or thirdly, by uniting and interweaving it ſelf with ſome other body that is already joyn'd with the tinging particles, with which ſubſtance it may have a *congruity*, though it have very little with the particles themſelves: or fourthly, it may alter the colour of a ting'd liquor by diſ-joyning certain particles which were before united with the tinging particles, which though they were ſomewhat *congruous* to theſe particles, have yet a greater *congruity* with the newly *infus'd Saline menſtruum*. It may likewiſe alter the colour by further diſſolving the tinging ſubſtance into ſmaller and ſmaller *particles*, and ſo *diluting* the colour; or by uniting ſeveral *particles* together as in precipitations, and ſo deepning it, and ſome ſuch other ways, which many experiments and compariſons of differing trials together, might eaſily inform one of.

From theſe Principles applied, may be made out all the varieties of colours obſervable, either in liquors, or any other ting'd bodies, with great eaſe, and I hope intelligible enough, there being nothing in the *notion* of colour, or in the ſuppos'd production, but is very conceivable, and may be poſſible.

The greateſt difficulty that I find againſt this *Hypotheſis*, is, that there ſeem to be more diſtinct colours then two, that is, then Yellow and Blue. This Objection is grounded on this reaſon, that there are ſeveral Reds, which *diluted*, make not a Saffron or pale Yellow, and therefore Red, or Scarlet ſeems to be a third colour diſtinct from a deep degree of Yellow.

To which I anſwer, that Saffron affords us a deep Scarlet tincture, which may be *diluted* into as pale a Yellow as any, either by making a weak ſo-

lution

lution of the Saffron, by infusing a small parcel of it into a great quantity of liquor, as in spirit of Wine, or else by looking through a very thin quantity of the tincture, and which may be heightn'd into the loveliest Scarlet, by looking through a very thick body of this tincture, or through a thinner parcel of it, which is highly *impregnated* with the tinging body, by having had a greater quantity of the Saffron dissolv'd in a smaller parcel of the liquor.

Now, though there may be some particles of other tinging bodies that give a lovely Scarlet also, which though *diluted* never so much with liquor, or looked on through never so thin a parcel of ting'd liquor, will not yet afford a pale Yellow, but onely a kind of faint Red; yet this is no argument but that those ting'd particles may have in them the faintest degree of Yellow, though we may be unable to make them exhibit it; For that power of being *diluted* depending upon the divisibility of the ting'd body, if I am unable to make the tinging particles so thin as to exhibit that colour, it does not therefore follow, that the thing is impossible to be done; now, the tinging particles of some bodies are of such a nature, that unless there be found some way of comminuting them into less bulks then the liquor does dissolve them into, all the Rays that pass through them must necessarily receive a tincture so deep, as their appropriate refractions and bulks compar'd with the proprieties of the dissolving liquor must necessarily dispose them to empress, which may perhaps be a pretty deep Yellow, or pale Red.

And that this is not *gratis dictum*, I shall add one instance of this kind, wherein the thing is most manifest.

If you take Blue *Smalt*, you shall find, that to afford the deepest Blue, which *cæteris paribus* has the greatest particles or sands; and if you further divide, or grind those particles on a Grindstone, or *porphyry* stone, you may by *comminuting* the sands of it, *dilute* the Blue into as pale a one as you please, which you cannot do by laying the colour thin; for wheresoever any single particle is, it exhibits as deep a Blue as the whole mass. Now, there are other Blues, which though never so much ground, will not be *diluted* by grinding, because consisting of very small particles, very deeply ting'd, they cannot by grinding be actually separated into smaller particles then the operation of the fire, or some other dissolving *menstruum*, has reduc'd them to already.

Thus all kind of *Metalline* colours, whether *precipitated*, *sublim'd*, *calcin'd*, or otherwise prepar'd, are hardly chang'd by grinding, as *ultra marine* is not more *diluted*; nor is *Vermilion* or *Red-lead* made of a more faint colour by grinding; for the smallest particles of these which I have view'd with my greatest Magnifying-Glass, if they be well enlightned, appear very deeply ting'd with their peculiar colours; nor, though I have magnified and enlightned the particles exceedingly, could I in many of them, perceive them to be transparent, or to be whole particles, but the smallest specks that I could find among well ground *Vermilion* and *Red-lead*, seem'd to be a Red mass, compounded of a multitude of less and less motes, which sticking together, compos'd a bulk, not one thousand thousandth part of the smallest visible sand or mote. And

And this I find generally in moſt *Metalline* colours, that though they conſiſt of parts ſo exceedingly ſmall,yet are they very deeply ting'd,they being ſo ponderous, and having ſuch a multitude of terreſtrial particles throng'd into a little room; ſo that 'tis difficult to find any particle tranſparent or reſembling a pretious ſtone, though not impoſſible; for I have obſerv'd divers ſuch ſhining and reſplendent colours intermixt with the particles of *Cinnaber*, both natural and artificial, before it hath been ground and broken or flaw'd into *Vermilion*: As I have alſo in *Orpiment*, *Red-lead*, and *Biſe*, which makes me ſuppoſe, that thoſe *metalline* colours are by grinding, not onely broken and ſeparated actually into ſmaller pieces, but that they are alſo flaw'd and bruſed ,whence they, for the moſt part,become *opacous*,like flaw'd Cryſtal or Glaſs,&c. But for *Smalts* and *verditures*, I have been able with a *Microſcope* to perceive their particles very many of them tranſparent.

Now, that the others alſo may be tranſparent, though they do not appear ſo to the *Microſcope*,may be made probable by this Experiment: that if you take *ammel* that is almoſt *opacous*, and grind it very well on a *Porphyry*, or *Serpentine*, the ſmall particles will by reaſon of their flaws, appear perfectly *opacous*; and that 'tis the flaws that produce this *opacouſneſs*, may be argued from this, that particles of the ſame *Ammel* much thicker if unflaw'd will appear ſomewhat tranſparent even to the eye; and from this alſo, that the moſt tranſparent and clear Cryſtal, if heated in the fire, and then ſuddenly quenched, ſo that it be all over flaw'd, will appear *opacous* and white.

And that the particles of *Metalline* colours are tranſparent,may be argued yet further from this,that the Cryſtals,or *Vitriols* of all Metals,are tranſparent, which ſince they conſiſt of *metalline* as well as *ſaline* particles, thoſe *metalline* ones muſt be tranſparent, which is yet further confirm'd from this, that they have for the moſt part, *appropriate* colours; ſo the *vitriol* of Gold is Yellow; of Copper,Blue,and ſometimes Green; of Iron, green; of Tinn and Lead, a pale White; of Silver,a pale Blue,&c.

And next,the *Solution* of all Metals into *menſtruums* are much the ſame with the *Vitriols*, or Cryſtals. It ſeems therefore very probable, that thoſe colours which are made by the *precipitation* of thoſe particles out of the *menſtruums* by tranſparent *precipitating* liquors ſhould be tranſparent alſo. Thus Gold *precipitates* with *oyl of Tartar*, or *ſpirit of Vrine* into a brown Yellow. Copper with ſpirit of *Vrine* into a Mucous blue, which retains its tranſparency. A ſolution of ſublimate (as the ſame Illuſtrious Authour I lately mention'd ſhews in his 40. Experiment) *precipitates* with oyl of *Tartar per deliquium*, into an Orange colour'd *precipitate*; nor is it leſs probable, that the *calcination* of thoſe *Vitriols* by the fire,ſhould have their particles tranſparent: Thus *Saccarum Saturni*, or the *Vitriol of Lead* by *calcination* becomes a deep Orange-colour'd *minium*,which is a kind of *precipitation* by ſome Salt which proceeds from the fire; common *Vitriol calcin'd*, yields a deep Brown Red,&c.

A third Argument, that the particles of Metals are tranſparent, is, that being *calcin'd*, and melted with Glaſs, they tinge the Glaſs with tranſpa-

rent colours. Thus the *Calx* of Silver tinges the Glaſs on which it is anneal'd with a lovely Yellow, or Gold colour, *&c.*

And that the parts of Metals are tranſparent, may be farther argued from the tranſparency of Leaf-gold, which held againſt the light, both to the naked eye, and the *Microſcope*, exhibits a deep Green. And though I have never ſeen the other Metals *laminated* ſo thin, that I was able to perceive them tranſparent, yet, for Copper and Braſs, if we had the ſame conveniency for *laminating* them, as we have for Gold, we might, perhaps, through ſuch plates or leaves, find very differing degrees of Blue, or Green; for it ſeems very probable, that thoſe Rays that rebound from them ting'd, with a deep Yellow, or pale Red, as from Copper, or with a pale Yellow, as from Braſs, have paſt through them; for I cannot conceive how by reflection alone thoſe Rays can receive a tincture, taking any *Hypotheſis* extant.

So that we ſee there may a ſufficient reaſon be drawn from theſe inſtances, why thoſe colours which we are unable to *dilute* to the paleſt Yellow, or Blue, or Green, are not therefore to be concluded not to be a deeper degree of them; for ſuppoſing we had a great company of ſmall *Globular* eſſence Bottles, or round Glaſs bubbles, about the bigneſs of a Walnut, fill'd each of them with a very deep mixture of Saffron, and that every one of them did appear of a deep Scarlet colour, and all of them together did *exhibit* at a diſtance, a deep dy'd Scarlet body. It does not follow, becauſe after we have come nearer to this *congeries*, or maſs, and divided it into its parts, and examining each of its parts ſeverally or apart, we find them to have much the ſame colour with the whole maſs; it does not, I ſay, therefore follow, that if we could break thoſe *Globules* ſmaller, or any other ways come to ſee a ſmaller or thinner parcel of the ting'd liquor that fill'd thoſe bubbles, that that ting'd liquor muſt always appear Red, or of a Scarlet hue, ſince if Experiment be made, the quite contrary will enſue; for it is capable of being *diluted* into the paleſt Yellow.

Now, that I might avoid all the Objections of this kind, by exhibiting an Experiment that might by ocular proof convince thoſe whom other reaſons would not prevail with, I provided me a *Priſmatical Glaſs*, made hollow, juſt in the form of a Wedge, ſuch as is repreſented in the tenth *Figure* of the ſixth *Scheme.* The two *parallelogram* ſides A B C D, A B E F, which met at a point, were made of the cleareſt Looking-glaſs plates well ground and poliſh'd that I could get; theſe were joyn'd with hard cement to the *triangular* ſides, B C E, A D F, which were of Wood; the *Parallelogram* baſe B C E F, likewiſe was of Wood joyn'd on to the reſt with hard cement, and the whole *Priſmatical* Box was exactly ſtopt every where, but onely a little hole near the baſe was left, whereby the Veſſel could be fill'd with any liquor, or emptied again at pleaſure.

One of theſe Boxes (for I had two of them) I fill'd with a pretty deep tincture of *Aloes*, drawn onely with fair Water, and then ſtopt the hole with a piece of Wax, then, by holding this Wedge againſt the Light, and looking through it, it was obvious enough to ſee the tincture of the liquor near the edge of the Wedge where it was but very thin, to be a pale but

well colour'd Yellow, and further and further from the edge, as the liquor grew thicker and thicker,this tincture appear'd deeper and deeper, ſo that near the blunt end,which was ſeven Inches fromthe edge and three Inches and an half thick; it was of a deep and well colour'd Red. Now, the clearer and purer this tincture be, the more lovely will the deep Scarlet be, and the fouler the tincture be, the more dirty will the Red appear; ſo that ſome dirty tinctures have afforded their deepeſt Red much of the colour of burnt Oker or *Spaniſh* brown;others as lovely a colour as *Vermilion*, and ſome much brighter; but ſeveral others, according as the tinctures were worſe or more foul, exhibited various kinds of Reds, of very differing degrees.

The other of theſe Wedges, I fill'd with a moſt lovely tincture of Copper, drawn from the filings of it,with ſpirit of *Urine*, and this Wedge held as the former againſt the Light, afforded all manner of Blues, from the fainteſt to the deepeſt,ſo that I was in good hope by theſe two,to have produc'd all the varieties of colours imaginable; for I thought by this means to have been able by placing the two *Parallelogram* ſides together, and the edges contrary ways,to have ſo mov'd them to and fro one by another, as by looking through them in ſeveral places, and through ſeveralthickneſſes, I ſhould have compounded, and conſequently have ſeen all thoſe colours, which by other like compoſitions of colours would have enſued.

But inſteed of meeting with what I look'd for, I met with ſomewhat more admirable; and that was, that I found my ſelf utterly unable to ſee through them when placed both together, though they were tranſparent enough when aſunder; and though I could ſee through twice the thickneſs, when both of them were fill'd with the ſame colour'd liquors, whether both with the Yellow, or both with the Blue, yet when one was fill'd with the Yellow, the other with the Blue,and both looked through, they both appear'd dark, onely when the parts near the tops were look'd through, they exhibited Greens, and thoſe of very great variety, as I expected,but the Purples and other colours,I could not by any means make, whether I endeavour'd to look through them both againſt the Sun, or whether I plac'd them againſt the hole of a darkned room.

But notwithſtanding this miſ-gheſſing, I proceeded on with my trial in a dark room, and having two holes near one another, I was able, by placing my Wedges againſt them,to mix the ting'd Rays that paſt through them, and fell on a ſheet of white Paper held at a convenient diſtance from them as I pleas'd; ſo that I could make the Paper appear of what colour I would,by varying the thickneſſes of the Wedges,and conſequently the tincture of the Rays that paſt through the two holes, and ſometimes alſo by varying the Paper, that is, inſteed of a white Paper, holding a gray, or a black piece of Paper.

Whence I experimentally found what I had before imagin'd, that all the varieties of colours imaginable are produc'd from ſeveral degrees of theſe two colours, namely, Yellow and Blue, or the mixture of them with light and darkneſs, that is, white and black. And all thoſe almoſt infinite varieties which Limners and Painters are able to make by compounding

pounding those several colours they lay on their Shels or *Palads*, are nothing else, but some *compositum*, made up of some one or more, or all of these four.

Now, whereas it may here again be objected, that neither can the Reds be made out of the Yellows, added together, or laid on in greater or less quantity, nor can the Yellows be made out of the Reds though laid never so thin; and as for the addition of White or Black, they do nothing but either whiten or darken the colours to which they are added, and not at all make them of any other kind of colour: as for instance, *Vermilion*, by being temper'd with White Lead, does not at all grow more Yellow, but onely there is made a whiter kind of Red. Nor does Yellow *Oker*, though laid never so thick, produce the colour of *Vermilion*, nor though it be temper'd with Black, does it at all make a Red; nay, though it be temper'd with White, it will not afford a fainter kind of Yellow, such as *masticut*, but onely a whiten'd Yellow; nor will the Blues be *diluted* or deepned after the manner I speak of, as *Indico* will never afford so fine a Blue as *Ultramarine* or *Bise*; nor will it, temper'd with *Vermilion*, ever afford a Green, though each of them be never so much temper'd with white.

To which I answer, that there is a great difference between *diluting* a colour and whitening of it; for *diluting* a colour, is to make the colour'd parts more thin, so that the ting'd light, which is made by trajecting those ting'd bodies, does not receive so deep a tincture; but whitening a colour is onely an intermixing of many clear reflections of light among the same ting'd parts; deepning also, and darkning or blacking a colour, are very different; for deepning a colour, is to make the light pass through a greater quantity of the same tinging body; and darkning or blacking a colour, is onely interposing a multitude of dark or black spots among the same ting'd parts, or placing the colour in a more faint light.

First therefore, as to the former of these operations, that is, diluting and deepning, most of the colours us'd by the Limners and Painters are incapable of, to wit, *Vermilion* and *Red-lead*, and *Oker*, because the ting'd parts are so exceeding small, that the most curious Grindstones we have, are not able to separate them into parts actually divided so small as the ting'd particles are; for looking on the most curiously ground *Vermilion*, and *Oker*, and *Red-lead*, I could perceive that even those small *corpuscles* of the bodies they left were compounded of many pieces, that is, they seem'd to be small pieces compounded of a multitude of lesser ting'd parts: each piece seeming almost like a piece of Red Glass, or ting'd Crystal all flaw'd; so that unless the Grindstone could actually divide them into smaller pieces then those flaw'd particles were, which compounded that ting'd mote I could see with my *Microscope*, it would be impossible to *dilute* the colour by grinding, which, because the finest we have will not reach to do in *Vermilion* or *Oker*, therefore they cannot at all, or very hardly be *diluted*.

Other colours indeed, whose ting'd particles are such as may be made smaller, by grinding their colour, may be *diluted*. Thus several of the

Blues may be *diluted*, as *Smalt* and *Bise*; and *Masticut*, which is Yellow, may be made more faint: And even *Vermilion* it ſelf may, by too much grinding, be brought to the colour of *Red-lead*, which is but an Orange colour, which is confeſt by all to be very much upon the Yellow. Now, though perhaps ſomewhat of this *diluting* of *Vermilion* by overmuch grinding may be attributed to the Grindſtone, or muller, for that ſome of their parts may be worn off and mixt with the colour, yet there ſeems not very much, for I have done it on a Serpentine-ſtone with a muller made of a Pebble, and yet obſerv'd the ſame effect follow.

And ſecondly, as to the other of theſe operations on colours, that is, the deepning of them, Limners and Painters colours are for the moſt part alſo uncapable. For they being for the moſt part *opacous*; and that *opacouſneſs*, as I ſaid before, proceeding from the particles, being very much flaw'd, unleſs we were able to joyn and re-unite thoſe flaw'd particles again into one piece, we ſhall not be able to deepen the colour, which ſince we are unable to do with moſt of the colours which are by Painters accounted *opacous*, we are therefore unable to deepen them by adding more of the ſame kind.

But becauſe all thoſe *opacous* colours have two kinds of beams or Rays reflected from them, that is, Rays unting'd, which are onely reflected from the outward ſurface, without at all penetrating of the body, and ting'd Rays which are reflected from the inward ſurfaces or flaws after they have ſuffer'd a two-fold refraction; and becauſe that tranſparent liquors mixt with ſuch *corpuſcles*, do, for the moſt part, take off the former kind of reflection; therefore theſe colours mixt with Water or Oyl, appear much deeper than when dry, for moſt part of that white reflection from the outward ſurface is remov'd. Nay, ſome of theſe colours are very much deepned by the mixture with ſome tranſparent liquor, and that becauſe they may perhaps get between thoſe two flaws, and ſo conſequently joyn two or more of thoſe flaw'd pieces together; but this happens but in a very few.

Now, to ſhew that all this is not *gratis dictum*, I ſhall ſet down ſome Experiments which do manifeſt theſe things to be probable and likely, which I have here deliver'd.

For, firſt, if you take any ting'd liquor whatſoever, eſpecially if it be pretty deeply ting'd, and by any means work it into a froth, the *congeries* of that froth ſhall ſeem an *opacous* body, and appear of the ſame colour, but much whiter than that of the liquor out of which it is made. For the abundance of reflections of the Rays againſt thoſe ſurfaces of the bubbles of which the froth conſiſts, does ſo often rebound the Rays backwards, that little or no light can paſs through, and conſequently the froth appears *opacous*.

Again, if to any of theſe ting'd liquors that will endure the boiling there be added a ſmall quantity of fine flower (the parts of which through the *Microſcope* are plainly enough to be perceiv'd to conſiſt of tranſparent *corpuſcles*) and ſuffer'd to boyl till it thicken the liquor, the maſs of the liquor will appear *opacous*, and ting'd with the ſame colour, but very much whiten'd.

Thus

Thus, if you take a piece of tranſparent Glaſs that is well colour'd, and by heating it, and then quenching it in Water, you flaw it all over; it will become *opacous*, and will exhibit the ſame colour with which the piece is ting'd, but fainter and whiter.

Or, if you take a Pipe of this tranſparent Glaſs, and in the flame of a Lamp melt it, and then blow it into very thin bubbles, then break thoſe bubbles, and collect a good parcel of thoſe *laminæ* together in a Paper, you ſhall find that a ſmall thickneſs of thoſe Plates will conſtitute an *opacous* body, and that you may ſee through the maſs of Glaſs before it be thus *laminated*, above four times the thickneſs: And beſides, they will now afford a colour by reflection as other *opacous* (as they are call'd) colours will, but much fainter and whiter than that of the Lump or Pipe out of which they were made.

Thus alſo, if you take *Putty*, and melt it with any tranſparent colour'd Glaſs, it will make it become an *opacous* colour'd lump, and to yield a paler and whiter colour than the lump by reflection.

The ſame thing may be done by a preparation of *Antimony*, as has been ſhewn by the Learned *Phyſician*, Dr. *C. M.* in his Excellent Obſervations and Notes on *Nery's Art of Glaſs*; and by this means all tranſparent colours become *opacous*, or *ammels*. And though by being ground they loſe very much of their colour, growing much whiter by reaſon of the multitude of ſingle reflections from their outward ſurface, as I ſhew'd afore, yet the fire that in the nealing or melting re-unites them, and ſo renews thoſe *ſpurious* reflections, removes alſo thoſe whitenings of the colour that proceed from them.

As for the other colours which Painters uſe, which are tranſparent, and us'd to varniſh over all other paintintings, 'tis well enough known that the laying on of them thinner or thicker, does very much *dilute* or deepen their colour.

Painters Colours therefore conſiſting moſt of them of ſolid particles, ſo ſmall that they cannot be either re-united into thicker particles by any Art yet known, and conſequently cannot be deepned; or divided into particles ſo ſmall as the flaw'd particles that exhibit that colour, much leſs into ſmaller, and conſequently cannot be *diluted*; It is neceſſary that they which are to imitate all kinds of colours, ſhould have as many degrees of each colour as can be procur'd.

And to this purpoſe, both Limners and Painters have a very great variety both of Yellows and Blues, beſides ſeveral other colour'd bodies that exhibit very compounded colours, ſuch as Greens and Purples; and others that are compounded of ſeveral degrees of Yellow, or ſeveral degrees of Blue, ſometimes unmixt, and ſometimes compounded with ſeveral other colour'd bodies.

The Yellows, from the paleſt to the deepeſt Red or Scarlet, which has no intermixture of Blue, are *pale and deep Maſticut, Orpament, Engliſh Oker, brown Oker, Red Lead, and Vermilion, burnt Engliſh Oker, and burnt brown Oker*, which laſt have a mixture of dark or dirty parts with them, &c.

Their

Their Blues are ſeveral kinds of *Smalts*, and *Verditures*, and *Biſe*, and *Ultramarine*, and *Indico*, which laſt has many dirty or dark parts intermixt with it.

Their compounded colour'd bodies, as *Pink*, and *Verdigreſe*,which are Greens, the one a *Popingay*, the other a *Sea-green*; then *Lac*,which is a very lovely *Purple*.

To which may be added their Black and White, which they alſo uſually call Colours, of each of which they have ſeveral kinds, ſuch as *Bone Black*, made of *Ivory* burnt in a cloſe Veſſel, and *Blue Black*, made of the ſmall coal of *Willow*, or ſome other Wood; and *Cullens earth*, which is a kind of brown Black, *&c*. Their uſual Whites are either artificial or natural *White Lead*, the laſt of which is the beſt they yet have; and with the mixing and tempering theſe colours together, are they able to make an imitation of any colour whatſoever: Their Reds or deep Yellows, they can *dilute* by mixing pale Yellows with them, and deepen their pale by mixing deeper with them; for it is not with *Opacous* colours as it is with tranſparent, where by adding more Yellow to yellow, it is deepned, but in *opacous diluted*. They can whiten any colour by mixing White with it, and darken any colour by mixing Black, or ſome dark and dirty colour. And in a word, moſt of the colours, or colour'd bodies they uſe in Limning and Painting, are ſuch, as though mixt with any other of their colours, they preſerve their own hue, and by being in ſuch very ſmal parts diſpers'd through the other colour'd bodies, they both, or altogether repreſent to the eye a *compoſitum* of all; the eye being unable, by reaſon of their ſmalneſs, to diſtinguiſh the peculiarly colour'd particles, but receives them as one intire *compoſitum*: whereas in many of theſe, the *Microſcope* very eaſily diſtinguiſhes each of the compounding colours diſtinct, and exhibiting its own colour.

Thus have I by gently mixing *Vermilion* and *Biſe* dry, produc'd a very fine Purple,or mixt colour,but looking on it with the *Microſcope*, I could eaſily diſtinguiſh both the Red and the Blue particles, which did not at all produce the *Phantaſm* of Purple.

To ſumm up all therefore in a word, I have not yet found any ſolid colour'd body,that I have yet examin'd,perfectly *opacous*; but thoſe that are leaſt tranſparent are *Metalline* and *Mineral* bodies, whoſe particles generally, ſeeming either to be very ſmall, or very much flaw'd, appear for the moſt part *opacous*, though there are very few of them that I have look'd on with a *Microſcope*, that have not very plainly or circumſtantially manifeſted themſelves tranſparent.

And indeed, there ſeem to be ſo few bodies in the world that are *in minimis* opacous, that I think one may make it a rational *Query*, Whether there be any body abſolutely thus *opacous*? For I doubt not at all (and I have taken notice of very many circumſtances that make me of this mind) that could we very much improve the *Microſcope*, we might be able to ſee all thoſe bodies very plainly tranſparent, which we now are fain onely to gheſs at by circumſtances. Nay, the Object Glaſſes we yet make uſe of are ſuch, that they make many tranſparent bodies to the

eye,

eye, seem *opacous* through them, which if we widen the Aperture a little, and cast more light on the objects, and not charge the Glasses so deep, will again disclose their transparency.

Now, as for all kinds of colours that are dissolvable in Water, or other liquors, there is nothing so manifest, as that all those ting'd liquors are transparent; and many of them are capable of being *diluted* and compounded or mixt with other colours, and divers of them are capable of being very much chang'd and heightned, and fixt with several kinds of *Saline menstruums*. Others of them upon compounding, destroy or vitiate each others colours, and *precipitate*, or otherwise very much alter each others tincture. In the true ordering and *diluting*, and deepning, and mixing, and fixing of each of which, consists one of the greatest mysteries of the Dyers; of which particulars, because our *Microscope* affords us very little information, I shall add nothing more at present; but onely that with a very few tinctures order'd and mixt after certain ways, too long to be here set down, I have been able to make an appearance of all the various colours imaginable, without at all using the help of *Salts*, or *Saline menstruums* to vary them.

As for the mutation of Colours by *Saline menstruums*, they have already been so fully and excellently handled by the lately mention'd Incomparable *Authour*, that I can add nothing, but that of a multitude of trials that I made, I have found them exactly to agree with his Rules and Theories; and though there may be infinite instances, yet may they be reduc'd under a few Heads, and compris'd within a very few Rules. And generally I find, that *Saline menstruums* are most operative upon those colours that are Purple, or have some degree of Purple in them, and upon the other colours much less. The *spurious* pulses that compose which, being (as I formerly noted) so very neer the middle between the true ones, that a small variation throws them both to one side, or both to the other, and so consequently must make a vast mutation in the formerly appearing Colour.

Observ. XI. *Of* Figures *observ'd in small Sand.*

SAnd generally seems to be nothing else but exceeding small Pebbles, or at least some very small parcels of a bigger stone; the whiter kind seems through the *Microscope* to consist of small transparent pieces of some *pellucid* body, each of them looking much like a piece of *Alum*, or *Salt Gem*; and this kind of Sand is angled for the most part irregularly, without any certain shape, and the *granules* of it are for the most part flaw'd, though amongst many of them it is not difficult to find some that are perfectly *pellucid*, like a piece of clear Crystal, and divers likewise most curiously shap'd, much after the manner of the bigger *Striæ* of Crystal, or like the small Diamants I observ'd in certain Flints, of which I shall by and by relate; which last particular seems to argue, that this kind of Sand is not

made

made by the comminution of greater tranſparent Cryſtaline bodies, but by the *concretion* or *coagulation* of Water, or ſome other fluid body.

There are other kinds of courſer Sands, which are browner, and have their particles much bigger; theſe, view'd with a *Microſcope*, ſeem much courſer and more *opacous* ſubſtances, and moſt of them are of ſome irregularly rounded Figures; and though they ſeem not ſo *opacous* as to the naked eye, yet they ſeem very foul and cloudy, but neither do theſe want curiouſly tranſparent, no more than they do regularly figur'd and well colour'd particles, as I have often found.

There are multitudes of other kinds of Sands, which in many particulars, plainly enough diſcoverable by the *Microſcope*, differ both from theſe laſt mention'd kinds of Sands, and from one another: there ſeeming to be as great variety of Sands, as there is of Stones. And as amongſt Stones ſome are call'd precious from their excellency, ſo alſo are there Sands which deſerve the ſame Epithite for their beauty; for viewing a ſmall parcel of *Eaſt-India* Sand (which was given me by my highly honoured friend, Mr. *Daniel Colwall*) and, ſince that, another parcel, much of the ſame kind, I found ſeveral of them, both very tranſparent like precious Stones, and regularly figur'd like Cryſtal, *Corniſh* Diamants, ſome Rubies, *&c.* and alſo ting'd with very lively and deep colours, like *Rubys*, *Saphyrs*, *Emeralds*, &c. Theſe kinds of granuls I have often found alſo in *Engliſh* Sand. And 'tis eaſie to make ſuch a counterfeit Sand with deeply ting'd Glaſs, Enamels and Painters colours.

It were endleſs to deſcribe the multitudes of Figures I have met with in theſe kind of minute bodies, ſuch as *Spherical*, *Oval*, *Pyramidal*, *Conical*, *Priſmatical*, of each of which kinds I have taken notice.

But amongſt many others, I met with none more obſervable than this pretty Shell (deſcribed in the *Figure* X. of the fifth *Scheme*) which, though as it was light on by chance, deſerv'd to have been omitted (I being unable to direct any one to find the like) yet for its rarity was it not inconſiderable, eſpecially upon the account of the information it may afford us. For by it we have a very good inſtance of the curioſity of Nature in another kind of Animals which are remov'd, by reaſon of their minuteneſs, beyond the reach of our eyes; ſo that as there are ſeveral ſorts of Inſects, as Mites, and others, ſo ſmall as not yet to have had any names; (ſome of which I ſhall afterwards deſcribe) and ſmall Fiſhes, as Leeches in Vineger; and ſmal vegetables, as Moſs, and Roſe-Leave-plants; and ſmall Muſhroms, as mould: ſo are there, it ſeems, ſmall Shel-fiſh likewiſe, Nature ſhewing her curioſity in every Tribe of *Animals*, *Vegetables*, and *Minerals*.

I was trying ſeveral ſmall and ſingle Magnifying Glaſſes, and caſually viewing a parcel of white Sand, when I perceiv'd one of the grains exactly ſhap'd and wreath'd like a Shell, but endeavouring to diſtinguiſh it with my naked eye, it was ſo very ſmall, that I was fain again to make uſe of the Glaſs to find it; then, whileſt I thus look'd on it, with a Pin I ſeparated all the reſt of the granules of Sand, and found it afterwards to appear to the naked eye an exceeding ſmall white ſpot, no bigger than the point of a

Pin,

Pin. Afterwards I view'd it every way with a better *Microſcope*, and found it on both ſides, and edge-ways, to reſemble the Shell of a ſmall Water-Snail with a flat ſpiral Shell: it had twelve wreathings, *a*, *b*, *c*, *d*, *e*, &c. all very proportionably growing one leſs than another toward the middle or center of the Shell, where there was a very ſmall round white ſpot. I could not certainly diſcover whether the Shell were hollow or not, but it ſeem'd fill'd with ſomewhat, and 'tis probable that it might be *petrify'd* as other larger Shels often are, ſuch as are mention'd in the ſeventeenth *Obſervation*.

Obſerv. XII. *Of* Gravel *in Urine.*

I Have often obſerv'd the Sand or Gravel of Urine, which ſeems to be a *tartareous* ſubſtance, generated out of a *Saline* and a *terreſtrial* ſubſtance *cryſtalliz'd* together, in the form of *Tartar*, ſometimes ſticking to the ſides of the *Urinal*, but for the moſt part ſinking to the bottom, and there lying in the form of coorſe common Sand; theſe, through the *Microſcope*, appear to be a company of ſmall bodies, partly tranſparent, and partly *opacous*, ſome White, ſome Yellow, ſome Red, others of more brown and duſkie colours.

The Figure of them is for the moſt part flat, in the manner of Slats, or ſuch like plated Stones, that is, each of them ſeem to be made up of ſeveral other thinner Plates, much like *Muſcovie Glaſs*, or *Engliſh Sparr*, to the laſt of which, the white plated Gravel ſeems moſt likely; for they ſeem not onely plated like that, but their ſides ſhap'd alſo into *Rhombs*, *Rhomboeids*, and ſometimes into *Rectangles* and *ſquares*. Their bigneſs and Figure may be ſeen in the ſecond *Figure* of the ſixth *Plate*, which repreſents about a dozen of them lying upon a plate A B C D, ſome of which, as *a*, *b*, *c*, *d*, ſeem'd more regular than the reſt, and *e*, which was a ſmall one, ſticking on the top of another, was a perfect *Rhomboeid* on the top, and had four *Rectangular* ſides.

The line E which was the meaſure of the *Microſcope*, is $\frac{1}{32}$ part of an *Engliſh* Inch, ſo that the greateſt bredth of any of them, exeeeded not $\frac{1}{128}$ part of an Inch.

Putting theſe into ſeveral liquors, I found *Oyl of Vitriol*, *Spirit of Urine*, and ſeveral other *Saline menſtruums* to diſſolve them; and the firſt of theſe in leſs than a minute without *Ebullition*, Water, and ſeveral other liquors, had no ſudden operation upon them. This I mention, becauſe thoſe liquors that diſſolve them, firſt make them very white, not *vitiating*, but rather rectifying their Figure, and thereby make them afford a very pretty object for the *Microſcope*.

How great an advantage it would be to ſuch as are troubled with the Stone, to find ſome *menſtruum* that might diſſolve them without hurting the Bladder, is eaſily imagin'd, ſince ſome *injections* made of ſuch bodies might likewiſe diſſolve the ſtone, which ſeems much of the ſame nature.

It may therefore, perhaps, be worthy ſome Phyſicians enquiry, whether there may not be ſomething mixt with the Urine in which the Gravel or Stone lies, which may again make it diſſolve it, the firſt of which ſeems by it's regular Figures to have been ſometimes *Cryſtalliz'd* out of it. For whether this *Cryſtallization* be made in the manner as *Alum*, *Peter*,&c. are *cryſtallized* out of a cooling liquor, in which, by boyling they have been diſſolv'd; or whether it be made in the manner of *Tartarum Vitriolatum*, that is, by the *Coalition* of an *acid* and a *Sulphureous* ſubſtance, it ſeems not impoſſible,but that the liquor it lies in,may be again made a *diſſolvent* of it. But leaving theſe inquiries to Phyſicians or Chymiſts, to whom it does more properly belong, I ſhall proceed.

Obſerv. XIII. *Of the ſmall* Diamants, *or* Sparks *in* Flints.

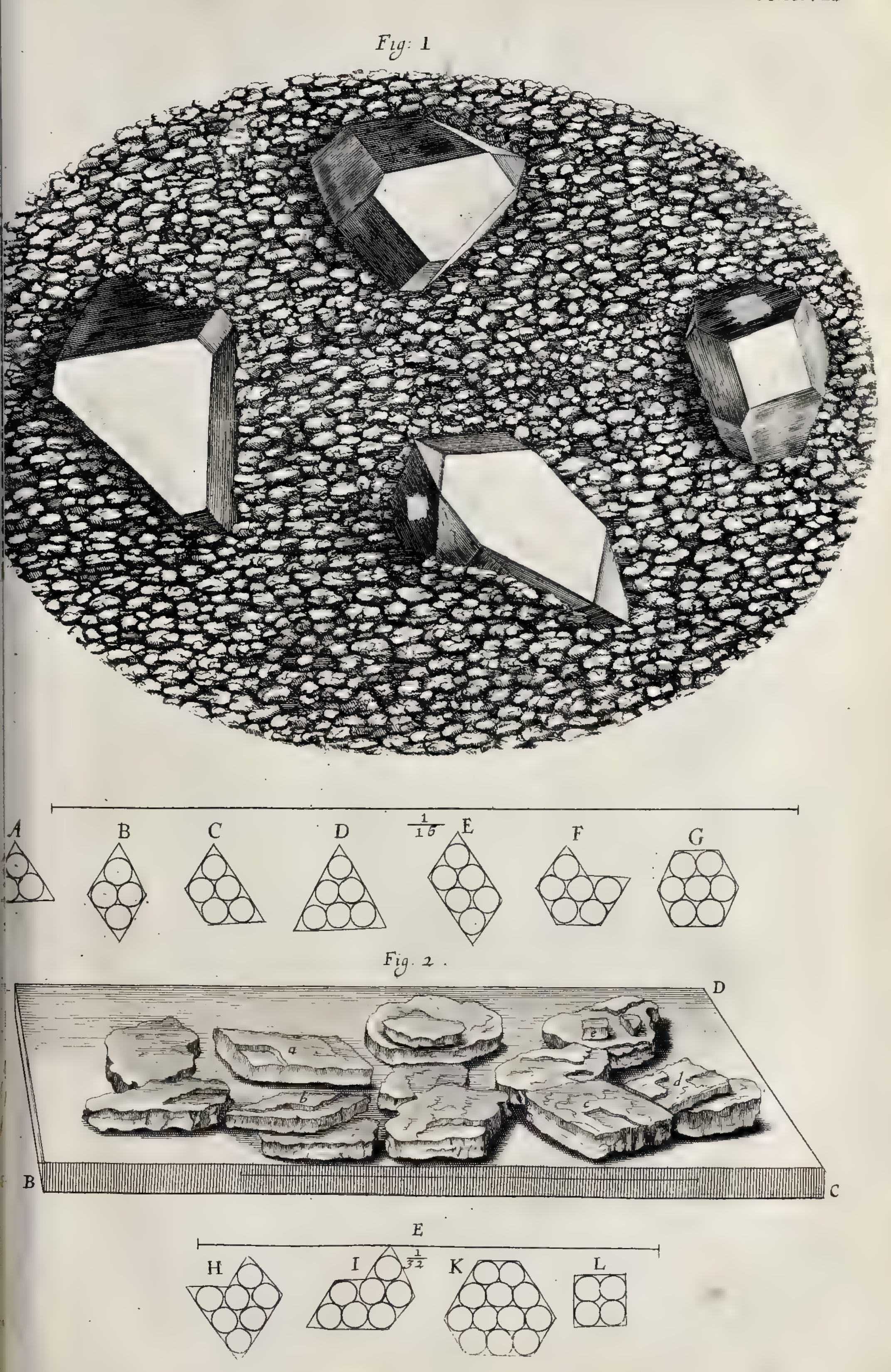
CHancing to break a Flint ſtone in pieces, I found within it a certain cavity all cruſted over with a very pretty candied ſubſtance, ſome of the parts of which, upon changing the poſture of the Stone, in reſpect of the *Incident* light, exhibited a number of ſmall, but very vivid reflections; and having made uſe of my *Microſcope*, I could perceive the whole ſurface of that cavity to be all beſet with a multitude of little *Cryſtaline* or *Adamantine* bodies, ſo curiouſly ſhap'd, that it afforded a not unpleaſing object.

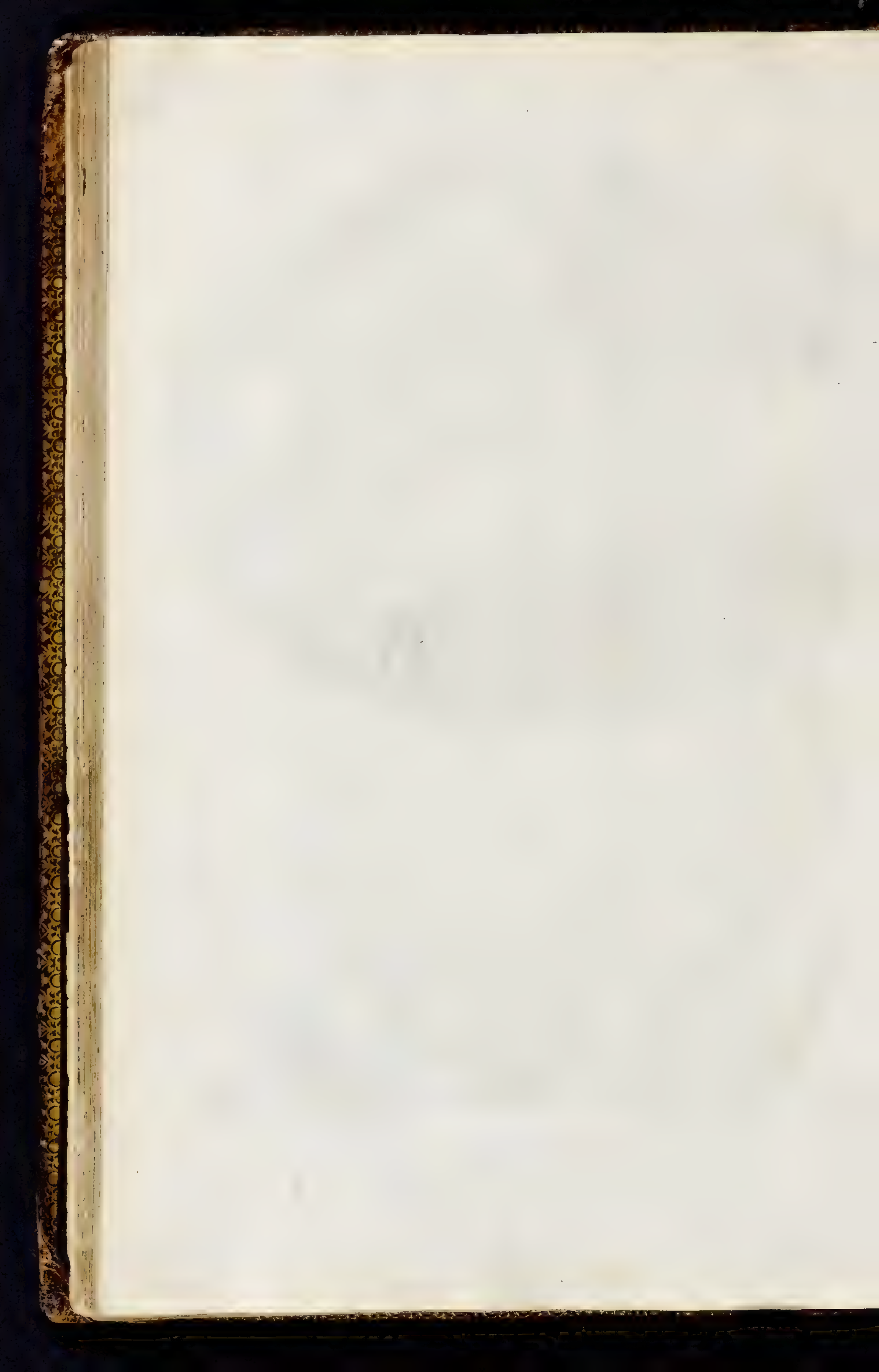
Having conſidered thoſe vivid *repercuſſions* of light,I found them to be made partly from the plain external ſurface of theſe regularly figured bodies (which afforded the vivid reflections) and partly to be made from within the ſomewhat *pellucid* body, that is,from ſome ſurface of the body,oppoſite to that ſuperficies of it which was next the eye.

And becauſe theſe bodies were ſo ſmall, that I could not well come to make Experiments and Examinations of them, I provided me ſeveral ſmall *ſtiriæ* of Cryſtals or Diamants, found in great quantities in *Cornwall*,and are therefore commonly called *Corniſh Diamants:* theſe being very *pellucid*, and growing in a hollow cavity of a Rock (as I have been ſeveral times informed by thoſe that have obſerv'd them) much after the ſame manner as theſe do in the Flint; and having beſides their outward ſurface very regularly ſhap'd, retaining very near the ſame Figures with ſome of thoſe I obſerv'd in the other, became a convenient help to me for the Examination of the proprieties of thoſe kinds of bodies.

And firſt for the Reflections; in theſe I found it very obſervable, That the brighteſt reflections of light proceeded from within the *pellucid* body; that is, that the Rays admitted through the *pellucid* ſubſtance in their getting out on the oppoſite ſide, were by the contiguous and ſtrong reflecting ſurface of the Air very vividly reflected, ſo that more Rays were reflected to the eye by this ſurface, though the Ray in entring and getting out of the Cryſtal had ſuffer'd a double refraction, than there were from the outward ſurface of the Glaſs where the Ray had ſuffer'd no refraction at all.

Sche:VII





And that this was the ſurface of the Air that gave ſo vivid a *re-percuſſion* I try'd by this means. I ſunk half of a *ſtiria* in Water, ſo that only Water was contiguous to the under ſurface, and then the internal reflection was ſo exceedingly faint, that it was ſcarce diſcernable. Again, I try'd to alter this vivid reflection by keeping off the Air, with a body not fluid, and that was by rubbing and holding my finger very hard againſt the under ſurface, ſo as in many places the pulp of my finger did touch the Glaſs, without any *interjacent* air between; then obſerving the reflection, I found, that whereſoever my finger or ſkin toucht the ſurface, from that part there was no reflection, but in the little furrows or creaſes of my ſkin, where there remain'd little ſmall lines of air, from them was return'd a very vivid reflection as before. I try'd further, by making the ſurface of very pure Quickſilver to be contiguous to the under ſurface of this *pellucid* body, and then the reflection from that was ſo exceedingly more vivid than from the air, as the reflection from air was than the reflection from the Water; from all which trials I plainly ſaw, that the ſtrong reflecting air was the cauſe of this *Phænomenon*.

And this agrees very well with the *Hypotheſis* of light and *Pellucid* bodies which I have mention'd in the deſcription of *Muſcovy-glaſs*; for we there ſuppoſe Glaſs to be a *medium*, which does leſs reſiſt the pulſe of light, and conſequently, that moſt of the Rays incident on it enter into it, and are refracted towards the *perpendicular*; whereas the air I ſuppoſe to be a body that does more reſiſt it, and conſequently more are *re-percuſs'd* then do enter it: the ſame kind of trials have I made, with *Cryſtalline Glaſs*, with drops of fluid bodies, and ſeveral other ways, which do all ſeem to agree very exactly with this *Theory*. So that from this Principle well eſtabliſh'd, we may deduce ſeverall Corollaries not unworthy obſervation.

And the firſt is, that it plainly appears by this, that the production of the Rainbow is as much to be aſcribed to the reflection of the concave ſurface of the air, as to the refraction of the *Globular* drops: this will be evidently manifeſt by theſe Experiments, if you *foliate* that part of a Glaſs-ball that is to reflect an *Iris*, as in the *Carteſian* Experiment, above mention'd, the reflections will be abundantly more ſtrong, and the colours more vivid: and if that part of the ſurface be touch'd with Watet, ſcarce affords any ſenſible colour at all.

Next we learn, that the great reaſon why *pellucid* bodies beaten ſmall are white, is from the multitude of reflections, not from the particles of the body, but from the *contiguous* ſurface of the air. And this is evidently manifeſted, by filling the *Interſtitia* of thoſe powder'd bodies with Water, whereby their whiteneſs preſently diſappears. From the ſame reaſon proceeds the whiteneſs of many kinds of Sands, which in the *Microſcope* appear to be made up of a multitude of little *pellucid* bodies, whoſe brighteſt reflections may by the *Microſcope* be plainly perceiv'd to come from their internal ſurfaces; and much of the whiteneſs of it may be deſtroy'd by the affuſion of fair Water to be contiguous to thoſe ſurfaces.

The whiteneſs alſo of froth, is for the moſt part to be aſcribed to the

reflection of the light from the ſurface of the air within the Bubbles,and very little to the reflection from the ſurface of the Water it ſelf: for this laſt reflection does not return a quarter ſo many Rays, as that which is made from the ſurface of the air,as I have certainly found by a multitude of Obſervations and Experiments.

The whiteneſs of *Linnen*, *Paper*, *Silk*, &c. proceeds much from the ſame reaſon, as the *Microſcope* will eaſily diſcover; for the Paper is made up of an abundance of *pellucid* bodies, which afford a very plentifull reflection from within, that is, from the concave ſurface of the air contiguous to its component particles; wherefore by the affuſion of Water, Oyl, Tallow, Turpentine, *&c.* all thoſe reflections are made more faint, and the beams of light are ſuffer'd to traject & run through the Paper more freely.

Hence further we may learn the reaſon of the whiteneſs of many bodies, and by what means they may be in part made *pellucid:* As white Marble for inſtance, for this body is compoſed of a *pellucid* body exceedingly flaw'd, that is, there are abundance of thin, and very fine cracks or chinks amongſt the multitude of particles of the body,that contain in them ſmall parcels of air,which do ſo *re-percuſs* and drive back the penetrating beams, that they cannot enter very deep within that body, which the *Microſcope* does plainly inform us to be made up of a *Congeries* of *pellucid* particles. And I further found it ſomewhat more evidently by ſome attempts I made towards the making tranſparent Marble, for by heating the Stone a little, and ſoaking it in Oyl, Turpentine, Oyl of Turpentine, *&c*, I found that I was able to ſee much deeper into the body of Marble then before; and one trial, which was not with an unctuous ſubſtance,ſucceeded better than the reſt, of which, when I have a better opportunity, I ſhall make further trial.

This alſo gives us a probable reaſon of the ſo much admired *Phænomena* of the *Oculus Mundi*, an *Oval* ſtone, which commonly looks like white Alabaſter, but being laid a certain time in Water, it grows *pellucid*, and tranſparent, and being ſuffer'd to lie again dry, it by degrees loſes that tranſparency, and becomes white as before. For the Stone being of a hollow ſpongie nature, has in the firſt and laſt of theſe appearances, all thoſe pores fill'd with the obtunding and reflecting air; whereas in the ſecond, all thoſe pores are fill'd with a *medium* that has much the ſame refraction with the particles of the Stone, and therefore thoſe two being *contiguous*, make,as 'twere, one *continued medium*, of which more is ſaid in the 15. *Obſervation.*

There are a multitude of other *Phænomena*,that are produc'd from this ſame Principle, which as it has not been taken notice of by any yet that I know, ſo I think, upon more diligent obſervation, will it not be found the leaſt conſiderable. But I have here onely time to hint *Hypotheſes*, and not to proſecute them ſo fully as I could wiſh; many of them having a vaſt extent in the production of a multitude of *Phænomena*, which have been by others,either not attempted to be explain'd, or elſe attributed to ſome other cauſe than what I have aſſign'd, and perhaps than the right; and therefore I ſhall leave this to the proſecution of ſuch as have more leiſure:

onely

onely before I leave it, I muſt not pretermit to hint, that by this Principle, multitudes of the *Phænomena* of the air,as about *Miſts*, *Clouds*, *Meteors*, *Haloes*,&c. are moſt plainly and (perhaps) truly explicable; multitudes alſo of the *Phænomena* in colour'd bodies, as liquors, *&c.* are deducible from it.

And from this I ſhall proceed to a ſecond conſiderable *Phænomenon* which theſe Diamants exhibit, and that is the regularity of their *Figure*, which is a propriety not leſs general than the former; It compriſing within its extent, all kinds of *Metals*, all kinds of *Minerals*,moſt *Precious ſtones*, all kinds of *Salts*,multitudes of *Earths*,and almoſt all kinds of *fluid bodies*. And this is another propiety, which, though a little ſuperficially taken notice of by ſome, has not, that I know, been ſo much as attempted to be explicated by any.

This propriety of bodies,as I think it the moſt worthy, and next in order to be conſider'd after the contemplation of the *Globular Figure*, ſo have I long had a deſire as wel as a determination to have proſecuted it if I had had an opportunity,having long ſince propos'd to my ſelf the method of my enquiry therein, it containing all the allurements that I think any enquiry is capable of: For,firſt I take it to proceed from the moſt ſimple principle that any kind of form can come from, next the *Globular*, which was therefore the firſt I ſet upon, and what I have therein perform'd, I leave the Judicious Reader to determine. For as that form proceeded from a propiety of fluid bodies, which I have call'd *Congruity*, or *Incongruity*; ſo I think, had I time and opportunity, I could make probable, that all theſe regular Figures that are ſo conſpicuouſly *various* and *curious*, and do ſo adorn and beautifie ſuch multitudes of bodies, as I have above hinted,ariſe onely from three or four ſeveral poſitions or poſtures of *Globular* particles,and thoſe the moſt plain,obvious, and neceſſary conjunctions of ſuch figur'd particles that are poſſible, ſo that ſuppoſing ſuch and ſuch plain and obvious cauſes concurring the *coagulating particles* muſt neceſſarily compoſe a body of ſuch a determinate regular Figure, and no other; and this with as much neceſſity and obviouſneſs as a fluid body encompaſt with a *Heterogeneous* fluid muſt be protruded into a *Spherule* or *Globe*. And this I have *ad oculum* demonſtated with a company of bullets,and ſome few other very ſimple bodies; ſo that there was not any regular Figure,which I have hitherto met withall, of any of thoſe bodies that I have above named, that I could not with the compoſition of bullets or globules, and one or two other bodies, imitate, even almoſt by ſhaking them together. And thus for inſtance may we find that the *Globular* bullets will of themſelves,if put on an inclining plain,ſo that they may run together, naturally run into a *triangular* order, compoſing all the variety of figures that can be imagin'd to be made out of *æquilateral triangles*; and ſuch will you find,upon trial,all the ſurfaces of *Alum* to be compos'd of: For three bullets lying on a plain, as cloſe to one another as they can compoſe an *æquilatero-triangular* form, as in A in the 7.*Scheme*. If a fourth be joyn'd to them on either ſide as cloſely as it can, they four compoſe the moſt regular Rhombus conſiſting of two *æquilateral triangles*, as

as B. If a fifth be joyn'd to them on either ſide in as cloſe a poſition as it can, which is the propriety of the *Texture*, it makes a *Trapezium*, or four-ſided Figure, two of whoſe angles are 120. and two 60. degrees, as C. If a ſixth be added, as before, either it makes an *æquilateral triangle*, as D, or a Rhomboeid, as E, or an *Hex-angular Figure*, as F, which is compos'd of two *primary Rhombes*. If a ſeventh be added, it makes either an *æquilatero-hexagonal* Figure, as G, or ſome kind of ſix-ſided *Figure*, as H, or I. And though there be never ſo many placed together, they may be rang'd into ſome of theſe lately mentioned Figures, all the angles of which will be either 60. degrees, or 120. as the figure K. which is an *æquiangular hexagonal* Figure is compounded of 12. *Globules*, or may be of 25, or 27, or 36, or 42, *&c.* and by theſe kinds of texture, or poſition of globular bodies, may you find out all the variety of regular ſhapes, into which the ſmooth ſurfaces of *Alum* are form'd, as upon examination any one may eaſily find; nor does it hold only in ſuperficies, but in ſolidity alſo, for it's obvious that a fourth *Globule* laid upon the third in this texture, compoſes a regular *Tetrahedron*, which is a very uſual Figure of the *Cryſtals* of *Alum*. And (to haſten) there is no one Figure into which *Alum* is obſerv'd to be cryſtallized, but may by this texture of *Globules* be imitated, and by no other.

I could inſtance alſo in the Figure of *Sea-ſalt*, and *Sal-gem*, that it is compos'd of a texture of *Globules*, placed in a *cubical* form, as L, and that all the Figures of thoſe Salts may be imitated by this texture of *Globules*, and by no other whatſoever. And that the forms of *Vitriol* and of *Salt-Peter*, as alſo of *Cryſtal*, *Hore-froſt*, &c. are compounded of theſe two textures, but modulated by certain proprieties: But I have not here time to inſiſt upon, as I have not neither to ſhew by what means *Globules* come to be thus context, and what thoſe *Globules* are, and many other particulars requiſite to a full and intelligible explication of this propriety of bodies. Nor have I hitherto found indeed an opportunity of proſecuting the inquiry ſo farr as I deſign'd; nor do I know when I may, it requiring abundance of time, and a great deal of aſſiſtance to go through with what I deſign'd; the model of which was this:

Firſt, to get as exact and full a collection as I could, of all the differing kinds of Geometrical figur'd bodies, ſome three or four ſeveral bodies of each kind.

Secondly, with them to get as exact a Hiſtory as poſſibly I could learn of their places of Generation or finding, and to enquire after as many circumſtances that tended to the Illuſtrating of this Enquiry, as poſſibly I could obſerve.

Thirdly, to make as many trials as upon experience I could find requiſite, in Diſſolutions and Coagulations of ſeveral cryſtallizing Salts; for the needfull inſtruction and information in this Enquiry.

Fourthly, to make ſeveral trials on divers other bodies, as Metals, Minerals, and Stones, by diſſolving them in ſeveral *Menſtruums*, and cryſtalizing them, to ſee what Figures would ariſe from thoſe ſeveral *Compoſitums*.

Fifthly,

Fitfthly, to make Compoſitions and Coagulations of ſeveral Salts together into the ſame maſs, to obſerve of what Figure the product of them would be; and in all, to note as many circumſtances as I ſhould judge conducive to my Enquiry.

Sixthly, to enquire the cloſeneſs or rarity of the texture of theſe bodies, by examining their gravity, and their refraction, *&c.*

Seventhly, to enquire particularly what operations the fire has upon ſeveral kinds of Salts, what changes it cauſes in their Figures, Textures, or Energies.

Eighthly, to examine their manner of diſſolution, or acting upon thoſe bodies diſſoluble in them; The texture of thoſe bodies before and after the proceſs. And this for the Hiſtory.

Next for the Solution, To have examin'd by what, and how many means, ſuch and ſuch Figures, actions and effects could be produc'd poſſibly.

And laſtly, from all circumſtances well weigh'd, I ſhould have endeavoured to have ſhewn which of them was moſt likely, and (if the informations by theſe Enquiries would have born it) to have demonſtrated which of them it muſt be, and was.

But to proceed, As I believe it next to the Globular the moſt ſimple; ſo do I, in the ſecond place, judge it not leſs pleaſant; for that which makes an Enquiry pleaſant, are, firſt a noble *Inventum* that promiſes to crown the ſucceſsfull endeavour; and ſuch muſt certainly the knowledge of the efficient and concurrent cauſes of all theſe curious Geometrical Figures be, which has made the Philoſophers hitherto to conclude nature in theſe things to play the Geometrician, according to that ſaying of *Plato*, Ὁ Θεὸς γεωμετρεῖ. Or next, a great variety of matter in the Enquiry; and here we meet with nothing leſs than the *Mathematicks* of nature, having every day a new Figure to contemplate, or a variation of the ſame in another body,

Which do afford us a third thing; which will yet more ſweeten the Enquiry, and that is, a multitude of information; we are not ſo much to grope in the dark, as in moſt other Enquiries, where the *Inventum* is great; for having ſuch a multitude of inſtances to compare, and ſuch eaſie ways of generating, or compounding and of deſtroying the form, as in the *Solution* and *Cryſtallization* of Salts, we cannot but learn plentifull information to proceed by. And this will further appear from the univerſality of the Principle which Nature has made uſe of almoſt in all inanimate bodies. And therefore, as the contemplation of them all conduces to the knowledg of any one; ſo from a Scientifical knowledge of any one does follow the ſame of all, and every one.

And fourthly, for the uſefulneſs of this knowledge, when acquir'd, certainly none can doubt, that conſiders that it caries us a ſtep forward into the Labirinth of Nature, in the right way towards the end we propoſe our ſelves in all Philoſophical Enquiries: So that knowing what is the form of Inanimate or Mineral bodies, we ſhall be the better able to proceed in our next Enquiry after the forms of Vegetative

tive bodies; and last of all, of Animate ones, that seeming to be the highest step of natural knowledge that the mind of man is capable of.

Observ. XIV. *Of several kindes of frozen* Figures.

I Have very often in a Morning, when there has been a great *hoar-frost*, with an indifferently magnifying *Microscope*, observ'd the small *Stiriæ*, or Crystalline beard, which then usually covers the face of most bodies that lie open to the cold air, and found them to be generally *Hexangular prismatical* bodies, much like the long Crystals of *Salt-peter*, save onely that the ends of them were differing: for whereas those of *Nitre* are for the most part *pyramidal*, being terminated either in a point or edge; these of Frost were hollow, and the cavity in some seem'd pretty deep, and this cavity was the more plainly to be seen, because usually one or other of the six *parallelogram* sides was wanting, or at least much shorter then the rest.

But this was onely the Figure of the *Bearded hoar-frost*; and as for the particles of other kinds of *hoar-frosts*, they seem'd for the most part irregular, or of no certain Figure. Nay, the parts of those curious branchings, or *vortices*, that usually in cold weather tarnish the surface of Glass, appear through the *Microscope* very rude and unshapen, as do most other kinds of frozen *Figures*, which to the naked eye seem exceeding neat and curious, such as the Figures of *Snow*, frozen *Urine*, *Hail*, several *Figures* frozen in common Water, &c. Some Observations of each of which I shall hereunto annex, because if well consider'd and exami'nd, they may, perhaps, prove very instructive for the finding out of what I have endeavoured in the preceding Observation to shew, to be (next the *Globular Figure* which is caus'd by *congruity*, as I hope I have made probable in the sixth *Observation*) the most simple and plain operation of Nature, of which, notwithstanding we are yet ignorant.

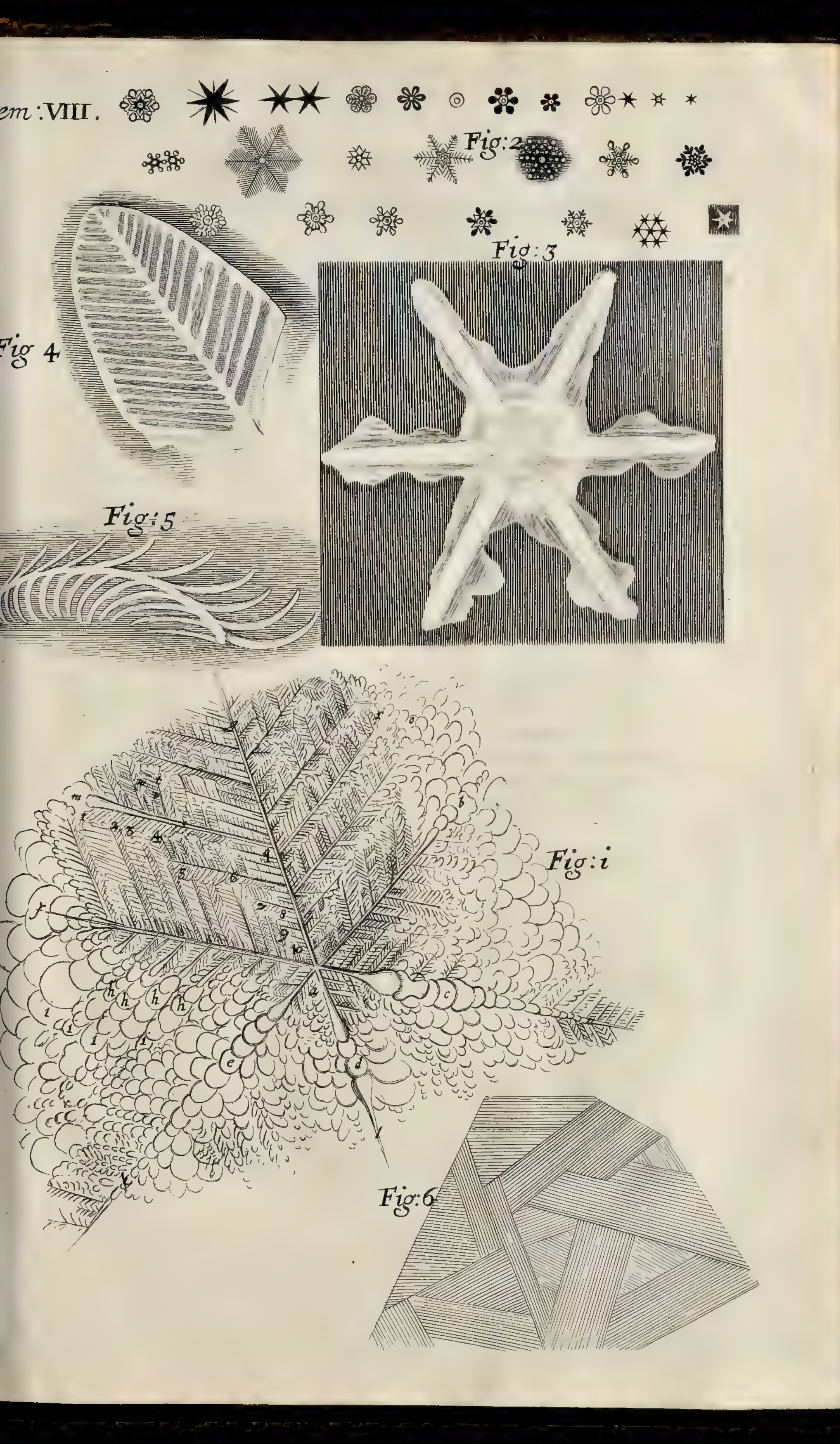
I.

Several Observables in the six-branched *Figures form'd on the surface of Urine by freezing.*

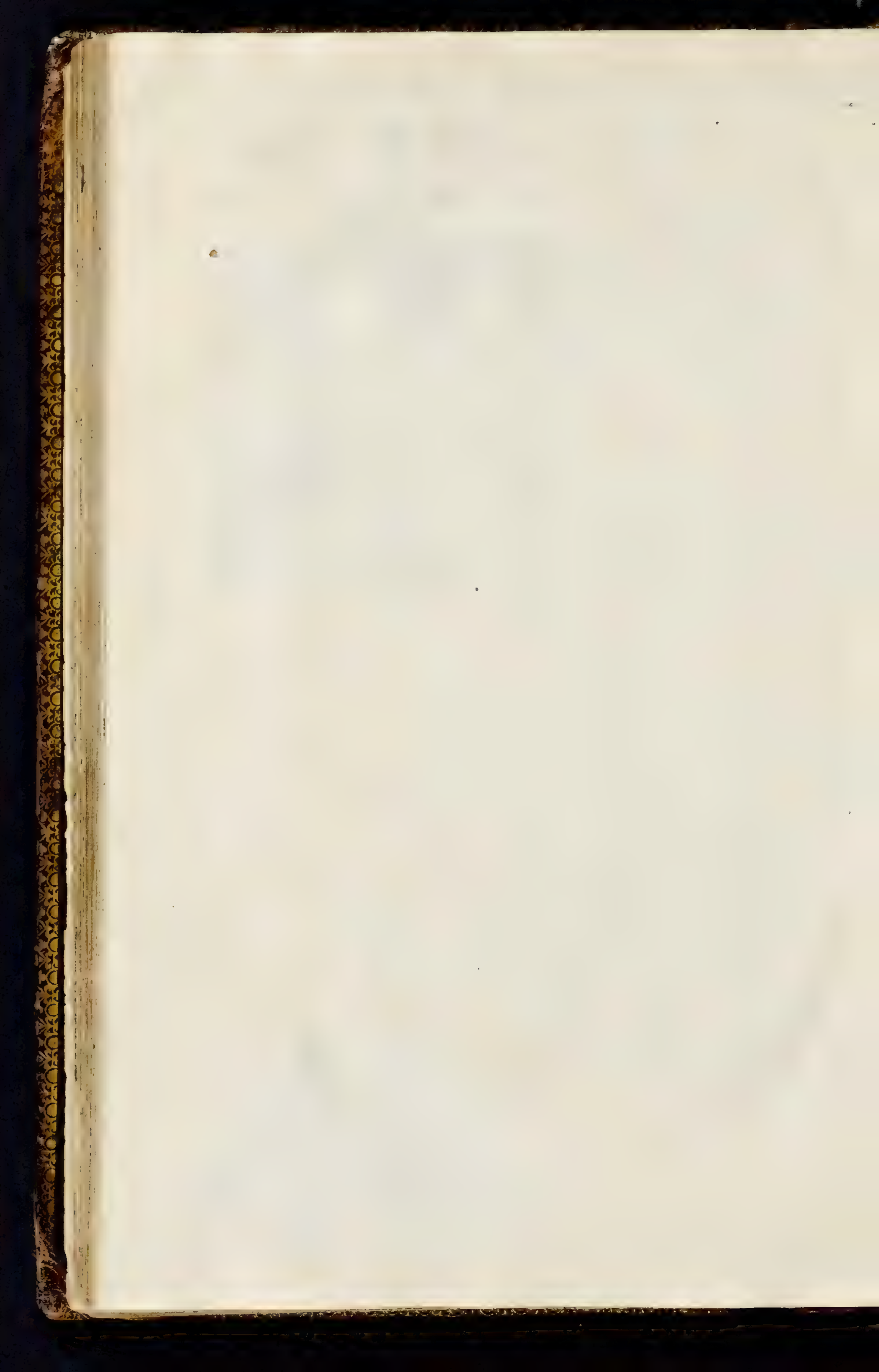
Schem. 8. Fig. 1.

1 The Figures were all frozen almost even with the surface of the *Urine* in the Vessel, but the bigger stems were a little *prominent* above that surface, and the parts of those stems which were nearest the center (*a*) were biggest above the surface.

2 I have observ'd several kinds of these Figures, some smaller, no bigger then a Two-pence, others so bigg, that I have by measure found one of its stems or branches above four foot long; and of these, some were pretty round, having all their branches pretty neer alike; other of them were more extended towards one side, as usually those very large ones were



em: VIII.
Fig:2
Fig:3
Fig 4
Fig:5
Fig:i
Fig:6



were, which I have obſerv'd in Ditches which have been full of foul water.

3 None of all theſe Figures I have yet taken notice of, had any regular poſition in reſpect of one another, or of the ſides of the Veſſel; nor did I find any of them equally to exactneſs extended every way from the center *a*.

4 Where ever there was a center,the branchings from it, *ab*, *ac*, *ad*, *ae*, *af*, *ag*, were never fewer, or more then ſix, which uſually concurr'd, or met one another very neer in the ſame point or center, *a*; though oftentimes not exactly; and were enclin'd to each other by an angle, of very neer ſixty degrees, I ſay, very neer, becauſe, though having endeavoured to meaſure them the moſt acurately I was able, with the largeſt Compaſſes I had, I could not find any ſenſible variation from that meaſure, yet the whole ſix-branched Figure ſeeming to compoſe a ſolid angle, they muſt neceſſarily be ſomewhat leſs.

5 The middle lines or ſtems of theſe branches, *a b*, *a c*, *a d*, *a e*, *a f*, *a g*, ſeem'd ſomewhat whiter, and a little higher then any of the *intermediate* branchings of theſe Figures; and the center *a*, was the moſt *prominent* part of the whole Figure, ſeeming the *apex* of a ſolid angle or *pyramid*, each of the ſix plains beinga little enclin'd below the ſurface of the *Urin*.

6 The lateral branchings iſſuing out of the great ones, ſuch as *op*, *m q*, &c. were each of them inclin'd to the great ones, by the ſame angle of about ſixty degrees,as the great ones were one to another, and always the bigger branchings were *prominent* above the leſs, and the leſs above the leaſt, by proportionate *gradations*.

7 The *lateral* branches ſhooting out of the great ones, went all of them from the center, and each of them was parallel to that great branch, next to which it lay; ſo that as all the branches on one ſide were parallel to one another, ſo were they all of them to the *approximate* great branch, as *p o*, *q r*, as they were parallel to each other,and ſhot from the center, ſo were they parallel alſo to the great branch *a b*.

8 Some of the ſtems of the ſix branches proceeded ſtraight, and of a thickneſs that gradually grew ſharper towards the end, as *ag*.

9 Others of the ſtems of thoſe branches grew bigger and knotty towards the middle, and the branches alſo as well as ſtems, from Cylinders grew into Plates, in a moſt admirable and curious order, ſo exceeding regular and delicate, as nothing could be more, as is viſible in *a b*, *a c*, *a d*, *a e*, *af*, but towards the end of ſome of theſe ſtems, they began again to grow ſmaller and to recover their former branchings, as about *k* and *n*.

10 Many of the *lateral* branches had *collateral* branches (if I may ſo call them) as *q m* had many ſuch as *ſ t*, and moſt of thoſe again *ſubcollateral*, as *v w*, and theſe again had others leſs, which one may call *lateroſubcollateral*, and theſe again others, and they others, *&c.* in greater Figures.

11 The branchings of the main Stems joyn'd not together by any regular line,nor did one ſide of the one lie over the other ſide of the other, but the ſmall *collateral* and *ſubcollateral* branches did lie at top of one

another according to a certain order or method, which I always obſerv'd to be this.

12 That ſide of a *collateral* or *ſubcollateral*, &c. branch, lay over the ſide of the *approximate* (as the feathers in the wing of a Bird) whoſe branchings proceeded parallel to the laſt biggeſt ſtem from which it ſprung, and not to the biggeſt ſtem of all, unleſs that were a ſecond ſtem backwards.

13 This rule that held in the branchings of the *Sexangular Figure* held alſo in the branchings of any other great or ſmall ſtem, though it did not proceed from a center.

14 The exactneſs and curioſity of the figuration of theſe branches, was in every particular ſo tranſcendent, that I judge it almoſt impoſſible for humane art to imitate.

15 Taſting ſeveral cleer pieces of this *Ice*, I could not find any *Vrinous* taſte in them, but thoſe few I taſted, ſeem'd as *inſipid* as water.

16 A figuration ſomewhat like this, though indeed in ſome particulars much more curious, I have ſeveral times obſerv'd in *regulus martis ſtellatus*, but with this difference, that all the ſtems and branchings are bended in a moſt excellent and regular order, whereas in *Ice* the ſtems and branchings are ſtreight, but in all other particulars it agrees with this, and ſeems indeed nothing but one of theſe ſtars, or branched Figures frozen on *Vrine*, diſtorted, or wreathed a little, with a certain proportion: *Lead* alſo that has *Arſenick* and ſome other things mixt with it, I have found to have its ſurface, when ſuffer'd to cool, figured ſomewhat like the branchings of *Vrine*, but much ſmaller.

17 But there is a *Vegetable* which does exceedingly imitate theſe branches, and that is, *Fearn*, where the main ſtem may be obſerv'd to ſhoot out branches, and the ſtems of each of theſe *lateral* branches, to ſend forth *collateral*, and thoſe *ſubcollateral*, and thoſe *latero ſubcollateral*, &c. and all thoſe much after the ſame order with the branchings, diviſions, and ſubdiviſions in the branchings of theſe Figures in frozen *Vrine*; ſo that if the Figures of both be well conſider'd, one would gheſs that there were not much greater need of a *ſeminal principle* for the production of *Fearn*, then for the production of the branches of *Vrine*, or the *Stella martis*, there ſeeming to be as much form and beauty in the one as in the other.

And indeed, this Plant of *Fearn*, if all particulars be well conſider'd, will ſeem of as ſimple, and uncompounded a form as any *Vegetable*, next to *Mould* or *Muſhromes*, and would next after the invention of the forms of thoſe, deſerve to be enquir'd into; for notwithſtanding ſeveral have affirm'd it to have ſeed, and to be propagated thereby; yet, though I have made very diligent enquiry after that particular, I cannot find that there is any part of it that can be imagin'd to be more ſeminal then another: But this onely here by the by:

For the freezing Figures in *Vrine*, I found it requiſite,

Firſt, that the Superficies be not diſturbed with any wind, or other commotion of the air, or the like.

Secondly,

Secondly, that it be not too long exposed, so as that the whole bulk be frozen, for oftentimes, in such cases, by reason of the swelling the of *Ice*, or from some other cause, the curious branched Figures disappear.

Thirdly, an artificial freezing with *Snow* and *Salt*, apply'd to the outside of the containing Vessel, succeeds not well, unless there be a very little quantity in the Vessel.

Fourthly, If you take any cleer and smooth Glass, and wetting all the inside of it with *Urine*, you expose it to a very sharp freezing, you will find it cover'd with a very regular and curious Figure.

II.

Observables in figur'd Snow.

Schem. 8. Fig. 1.

Exposing a piece of black Cloth, or a black Hatt to the falling *Snow*, I have often with great pleasure, observ'd such an infinite variety of curiously figur'd *Snow*, that it would be as impossible to draw the Figure and shape of every one of them, as to imitate exactly the curious and Geometrical *Mechanisme* of Nature in any one. Some coorse draughts, such as the coldness of the weather, and the ill provisions, I had by me for such a purpose, would permit me to make, I have here added in the Second *Figure* of the Eighth *Scheme*.

In all which I observ'd, that if they were of any regular Figures, they were always branched out with six principal branches, all of equal length, shape and make, from the center, being each of them inclin'd to either of the next branches on either side of it, by an angle of sixty degrees.

Now, as all these stems were for the most part in one flake exactly of the same make, so were they in differing Figures of very differing ones; so that in a very little time I have observ'd above an hundred several cizes and shapes of these starry flakes.

The branches also out of each stem of any one of these flakes, were exactly alike in the same flake; so that of whatever Figure one of the branches were, the other five were sure to be of the same, very exactly, that is, if the branchings of the one were small *Perallelipipeds* or Plates, the branchings of the other five were of the same; and generally, the branchings were very conformable to the rules and method observ'd before, in the Figures on *Urine*, that is, the branchings from each side of the stems were parallel to the next stem on that side, and if the stems were plated, the branches also were the same; if the stems were very long, the branches also were so, *&c.*

Observing some of these figur'd flakes with a *Microscope*, I found them not to appear so curious and exactly figur'd as one would have imagin'd, but like Artificial Figures, the bigger they were magnify'd, the more irregularites appear'd in them; but this irregularity seem'd ascribable to the thawing and breaking of the flake by the fall, and not at all to the defect of the *plastick* virtue of Nature, whose curiosity in the formation of most of these kind of regular Figures, such as those of *Salt*, *Minerals*, &c.

 appears

appears by the help of the *Microſcope*, to be very many degrees ſmaller then the moſt acute eye is able to perceive without it. And though one of theſe ſix-branched Stars appear'd here below much of the ſhape deſcribed in the Third *Figure* of the Eighth *Scheme*; yet I am very apt to think, that could we have a ſight of one of them through a *Microſcope* as they are generated in the Clouds before their Figures are vitiated by external accidents, they would exhibit abundance of curioſity and neatneſs there alſo, though never ſo much magnify'd: For ſince I have obſerv'd the Figures of *Salts* and *Minerals* to be ſome of them ſo exceeding ſmall, that I have ſcarcely been able to perceive them with the *Microſcope*, and yet have they been regular, and ſince (as far as I have yet examin'd it) there ſeems to be but one and the ſame cauſe that produces both theſe effects, I think it not irrational to ſuppoſe that theſe pretty figur'd Stars of *Snow*, when at firſt generated might be alſo very regular and exact.

III.

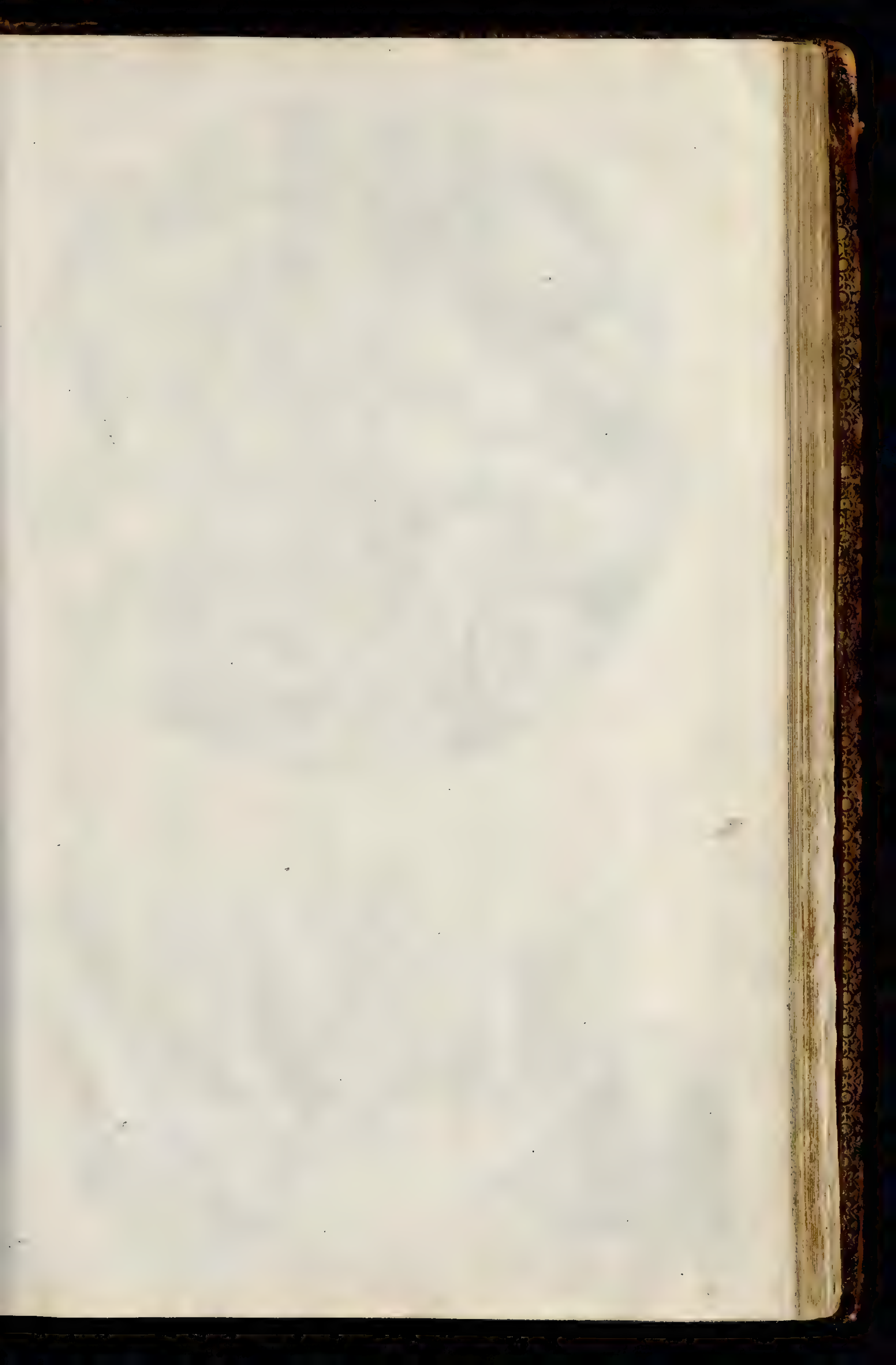
Several kinds of Figures in Water *frozen.*

Putting fair Water into a large capacious Veſſel of *Glaſs*, and expoſing it to the cold, I obſerv'd after a little time, ſeveral broad, flat, and thin *laminæ*, or plates of *Ice*, croſſing the bulk of the water and one another very irregularly, onely moſt of them ſeem'd to turn one of their edges towards that ſide of the Glaſs which was next it, and ſeem'd to grow, as 'twere from the inſide of the Veſſel inwards towards the middle, almoſt like ſo many blades of *Fern*. Having taken ſeveral of theſe plates out of water on the blade of a Knife, I obſerv'd them figur'd much after the manner of *Herring bones*, or *Fern blades*, that is, there was one bigger ſtem in the middle like the back-bone, and out of it, on either ſide, were a multitude of ſmall *ſtiriæ*, or *icicles*, like the ſmaller bones, or the ſmaller branches in *Fern*, each of theſe branches on the one ſide, were parallel to all the reſt on the ſame ſide, and all of them ſeem'd to make an angle with the ſtem, towards the top, of ſixty degrees, and towards the bottom or root of this ſtem, of 120. See the fourth *Figure* of the 8. *Plate*.

I obſerv'd likewiſe ſeveral very pretty varieties of Figures in Water, frozen on the top of a broad flat Marble-ſtone, expos'd to the cold with a little Water on it, ſome like feathers, ſome of other ſhapes, many of them were very much of the ſhape expreſt in the fifth Figure of the 8. *Scheme*, which is extremely differing from any of the other Figures.

I obſerv'd likewiſe, that the ſhootings of *Ice* on the top of Water, beginning to freez, were in ſtreight *priſmatical* bodies much like thoſe of *roch-peter*, that they croſt each other uſually without any kind of order or rule, that they were always a little higher then the ſurface of the Water that lay between them; that by degrees thoſe *interjacent* ſpaces would be fill'd with *Ice* alſo, which uſually would be as high as the ſurface of the reſt.

In flakes of *Ice* that had been frozen on the top of Water to any conſiderable



Figur : 1

a
a
a
a
a
b
b
d

Figur : 2.

Fig : 3.

ſiderable thickneſs, I obſerv'd that both the upper and the under ſides of it were curiouſly quill'd, furrow'd, or grain'd, as it were, which when the Sun ſhone on the Plate, was exceeding eaſily to be perceiv'd to be much after the ſhape of the lines in the 6. *Figure* of the 8. *Scheme*, that is, they conſiſted of ſeveral ſtreight ends of parallel Plates, which were of divers lengths and angles to one another without any certain order.

The cauſe of all which regular Figures (and of hundreds of others, namely of *Salts*, *Minerals*, *Metals*, &c. which I could have here inſerted, would it not have been too long) ſeems to be deducible from the ſame Principles,which I have (in the 13. *Obſervation*) hinted only, having not yet had time to compleat a *Theory* of them. But indeed (which I there alſo hinted) I judge it the ſecond ſtep by which the *Pyramid* of natural knowledge (which is the knowledge of the form of bodies) is to be aſcended: And whoſoever will climb it, muſt be well furniſh'd with that which the Noble *Verulam* calls *Scalam Intellectus*; he muſt have ſcaling Ladders, otherwiſe the ſteps are ſo large and high, there will be no getting up them, and conſequently little hopes of attaining any higher ſtation, ſuch as to the knowledge of the moſt ſimple principle of Vegetation manifeſted in Mould and Muſhromes, which, as I elſewhere endeavoured to ſhew, ſeems to be the third ſtep; for it ſeems to me, that the Intellect of man is like his body, deſtitute of wings, and cannot move from a lower to a higher and more ſublime ſtation of knowledg,otherwiſe then ſtep by ſtep,nay even there where the way is prepar'd and already made paſſible; as in the *Elements of Geometry*, or the like, where it is fain to climb a whole *ſeries* of Propoſitions by degrees, before it attains the knowledge of one *Probleme*. But if the aſcent be high, difficult and above its reach, it muſt have recourſe to a *novum organum*, ſome new engine and contrivance, ſome new kind of *Algebra*, or *Analytick Art* before it can ſurmount it.

Obſerv. XV. *Of* Kettering-ſtone, *and of the pores of* Inanimate *bodies.*

Schem. 9. Fig. 1.

THis Stone which is brought from *Kettering* in *Northampton-ſhire*,and digg'd out of a Quarry, as I am inform'd, has a grain altogether admirable, nor have I ever ſeen or heard of any other ſtone that has the like. It is made up of an innumerable company of ſmall bodies, not all of the ſame cize or ſhape, but for the moſt part, not much differing from a Globular form, nor exceed they one another in Diameter above three or four times; they appear to the eye, like the Cobb or Ovary of a *Herring*, or ſome ſmaller fiſhes, but for the moſt part, the particles ſeem ſomewhat leſs, and not ſo uniform; but their variation from a perfect globular ball,ſeems to be only by the preſſure of the *contiguous* bals which have a little depreſt and protruded thoſe toucht ſides inward, and forc'd the

the other ſides as much outwards beyond the limits of a Globe; juſt as it would happen, if a heap of exactly round Balls of ſoft Clay were heap'd upon one another; or, as I have often ſeen a heap of ſmall Globules of *Quickſilver*, reduc'd to that form by rubbing it much in a glaz'd Veſſel, with ſome ſlimy or ſluggiſh liquor, ſuch as Spittle, when though the top of the upper Globules be very neer ſpherical, yet thoſe that are preſt upon by others, exactly imitate the forms of theſe lately mention'd grains.

Where theſe grains touch each other, they are ſo firmly united or ſettled together, that they ſeldom part without breaking a hole in one or th'other of them, ſuch as *a, a, a, b, c, c*, &c. Some of which fractions, as *a, a, a, a,* where the touch has been but light, break no more then the outward cruſt, or firſt ſhell of the ſtone, which is of a white colour, a little daſh'd with a browniſh Yellow, and is very thin, like the ſhell of an Egg: and I have ſeen ſome of thoſe grains perfectly reſemble ſome kind of Eggs, both in colour and ſhape: But where the union of the *contiguous granules* has been more firm, there the divulſion has made a greater Chaſm, as at *b, b, b,* in ſo much that I have obſerv'd ſome of them quite broken in two, as at *c, c, c,* which has diſcovered to me a further reſemblance they have to Eggs, they having an appearance of a white and yelk, by two differing ſubſtances that envelope and encompaſs each other.

That which we may call the white was pretty whitiſh neer the yelk, but more duſkie towards the ſhell; ſome of them I could plainly perceive to be ſhot or radiated like a *Pyrites* or *fire-ſtone*; the yelk in ſome I ſaw hollow, in others fill'd with a duſkie brown and porous ſubſtance like a kind of pith.

The ſmall pores, or *interſtitia e e e e* betwixt the Globules, I plainly ſaw, and found by other trials to be every way pervious to air and water, for I could blow through a piece of this ſtone of a conſiderable thickneſs, as eaſily as I have blown through a Cane, which minded me of the pores which *Des Cartes* allow his *materia ſubtilis* between the *æthereal* globules.

The object, through the *Microſcope*, appears like a *Congeries* or heap of Pibbles, ſuch as I have often ſeen caſt up on the ſhore, by the working of the Sea after a great ſtorm, or like (in ſhape, though not colour) a company of ſmall Globules of Quickſilver, look'd on with a *Microſcope*, when reduc'd into that form by the way lately mentioned. And perhaps, this laſt may give ſome hint at the manner of the formation of the former: For ſuppoſing ſome *Lapideſcent* ſubſtance to be generated, or ſome way brought (either by ſome commixture of bodies in the Sea it ſelf, or protruded in, perhaps, out of ſome *ſubterraneous* caverns) to the bottom of the Sea, and there remaining in the form of a liquor like Quickſilver, *heterogeneous* to the ambient *Saline* fluid, it may by the working and tumblings of the Sea to and fro be jumbled and comminuted into ſuch Globules as may afterwards be hardned into Flints, the lying of which one upon another, when in the Sea, being not very hard, by reaſon of the weight of the incompaſſing fluid, may cauſe the undermoſt to be a little, though not much, varied from a globular Figure. But this only by the by.

After what manner this *Kettering-ſtone* ſhould be generated I cannot learn, having never been there to view the place, and obſerve the circumſtances; but it ſeems to me from the ſtructure of it to be generated from ſome ſubſtance once more fluid, and afterwards by degrees growing harder, almoſt after the ſame manner as I ſuppoſed the generation of Flints to be made.

But whatever were the cauſe of its curious texture, we may learn this information from it; that even in thoſe things which we account vile, rude, and coorſe, Nature has not been wanting to ſhew abundance of curioſity and excellent Mechaniſme.

We may here find a Stone by help of a *Microſcope*, to be made up of abundance of ſmall Balls, which do but juſt touch each other, and yet there being ſo many contacts, they make a firm hard maſs, or a Stone much harder then Free-ſtone.

Next, though we can by a *Microſcope* diſcern ſo curious a ſhape in the particles, yet to the naked eye there ſcarce appears any ſuch thing; which may afford us a good argument to think, that even in thoſe bodies alſo, whoſe *texture* we are not able to diſcern, though help'd with *Microſcopes*, there may be yet *latent* ſo curious a *Schematiſme*, that it may abundantly ſatisfie the curious ſearcher, who ſhall be ſo happy as to find ſome way to diſcover it.

Next, we here find a Stone, though to the naked eye a very cloſe one, yet every way perforated with innumerable pores, which are nothing elſe but the *interſtitia*, between thoſe multitudes of minute globular particles, that compoſe the bulk it ſelf; and theſe pores are not only diſcover'd by the *Microſcope*, but by this contrivance.

I took a pretty large piece of this ſtone, and covering it all over with cement, ſave only at two oppoſite parts, I found my ſelf able, by blowing in at one end that was left open, to blow my ſpittle, with which I had wet the other end, into abundance of bubbles, which argued theſe pores to be open and pervious through the whole ſtone, which affords us a very pretty inſtance of the porouſneſs of ſome ſeemingly cloſe bodies, of which kind I ſhall anon have occaſion to ſubjoyn many more, tending to prove the ſame thing.

I muſt not here omit to take notice, that in this body there is not a *vegetative* faculty that ſhould ſo contrive this ſtructure for any peculiar uſe of *Vegetation* or growth, whereas in the other inſtances of vegetable porous bodies, there is an *anima*, or *forma informans*, that does contrive all the Structures and *Mechaniſmes* of the conſtituting body, to make them ſubſervient and uſefull to the great Work or Function they are to perform. And ſo I gheſs the pores in Wood, and other vegetables, in bones, and other Animal ſubſtances, to be as ſo many channels, provided by the Great and Alwiſe Creator, for the conveyance of appropriated juyces to particular parts. And therefore, that this may tend, or be pervious all towards one part, and may have impediments, as valves or the like, to any other; but in this body we have very little reaſon to ſuſpect there ſhould be any ſuch deſign, for it is equally pervious every way, not onely forward,

ward, but backwards, and ſide-ways, and ſeems indeed much rather to be *Homogeneous* or ſimilar to thoſe pores, which we may with great probability believe to be the channels of *pellucid* bodies, not directed, or more open any one way, then any other, being equally pervious every way. And, according as theſe pores are more or greater in reſpect of the *interſtitial* bodies, the more tranſparent are the ſo conſtituted concretes; and the ſmaller thoſe pores are, the weaker is the *Impulſe* of light communicated through them, though the more quick be the progreſs.

Upon this Occaſion, I hope it will not be altogether unſeaſonable, if I propound my conjectures and *Hypotheſis* about the *medium* and conveyance of light.

I ſuppoſe then, that the greateſt part of the *Interſtitia* of the world, that lies between the bodies of the Sun and Starrs, and the Planets, and the Earth, to be an exceeding fluid body, very apt and ready to be mov'd, and to communicate the motion of any one part to any other part, though never ſo far diſtant: Nor do I much concern my ſelf, to determine what the Figure of the particles of this exceedingly ſubtile fluid *medium* muſt be; nor whether it have any interſtitiated pores or vacuities, it being ſufficient to ſolve all the *Phænomena* to ſuppoſe it an exceedingly fluid, or the moſt fluid body in the world, and as yet impoſſible to determine the other difficulties.

That being ſo exceeding fluid a body, it eaſily gives paſſage to all other bodies to move to and fro in it.

That it neither receives from any of its parts, or from other bodies; nor communicates to any of its parts, or to any other body, any impulſe, or motion in a direct line, that is not of a determinate quickneſs. And that when the motion is of ſuch determinate ſwiftneſs, it both receives, and communicates, or propagates an impulſe or motion to any imaginable diſtance in ſtreight lines, with an unimaginable celerity and vigour.

That all kind of ſolid bodies conſiſt of pretty maſſie particles in reſpect of the particles of this fluid *medium*, which in many places do ſo touch each other, that none of this fluid *medium* interpoſes much after the ſame mannner (to uſe a groſs ſimilitude) as a heap of great ſtones compaſs one great *congeries* or maſs in the midſt of the water.

That all fluid bodies which we may call *tangible*, are nothing but ſome more ſubtile parts of thoſe particles, that ſerve to conſtiture all *tangible* bodies.

That the water, and ſuch other fluid bodies, are nothing but a *congeries* of particles agitated or made fluid by it in the ſame manner as the particles of *Salt* are agitated or made fluid by a parcel of water, in which they are diſſolv'd, and ſubſiding to the bottom of it, conſtitute a fluid body, much more maſſie and denſe, and leſs fluid then the pure water it ſelf.

That the air on the other ſide is a certain company of particles of quite another kind, that is, ſuch as are very much ſmaller, and more eaſiely moveable by the motion of this fluid *medium*; much like thoſe very ſubtile parts of *Cochenel*, and other very deep tinging bodies, where by a very

ſmall

ſmall parcel of matter is able to tinge and diffuſe it ſelf over a very great quantity of the fluid diſſolvent; or ſomewhat after that manner, as ſmoak, and ſuch like minute bodies, or ſteams, are obſerv'd to tinge a very great quantity of air; onely this laſt ſimilitude is deficient in one propriety, and that is a perpetuity or continuance in that ſtate of commixture with the air, but the former does more neerly approach to the nature and manner of the air's being diſſolv'd by this fluid or *Æther*. And this Similitude will further hold in theſe proprieties; that as thoſe tinctures may be increaſed by certain bodies, ſo may they be precipitated by others; as I ſhall afterwards ſhew it to be very probable, that the like accidents happen even to the Air it ſelf.

Further, as theſe ſolutions and tinctures do alter the nature of theſe fluid bodies, as to their aptneſs to propagate a motion or impulſe through them, even ſo does the particles of the Air, Water, and other fluid bodies, and of Glaſs, Cryſtal, &c. which are commixt with this bulk of the *Æther*, alter the motion of the propagated pulſe of light; that is, where theſe more bulkie particles are more plentifull, and conſequently a leſſer quantity of the *Æther* between them to be mov'd, there the motion muſt neceſſarily be the ſwifter, though not ſo robuſt, which will produce thoſe effects, which I have (I hope) with ſome probability, aſcribed to it in the digreſſion about Colours, at the end of the *Obſervations* on *Muſcovy-glaſs*.

Now, that other Stones, and thoſe which have the cloſeſt and hardeſt textures, and ſeem (as far as we are able to diſcover with our eyes, though help'd with the beſt *Microſcopes*) freeſt from pores, are yet notwithſtanding repleniſh'd with them; an Inſtance or two will, I ſuppoſe, make more probable.

A very ſolid and unflaw'd piece of cleer white *Marble*, if it be well poliſh'd and glaz'd, has ſo curiouſly ſmooth a ſurface, that the beſt and moſt poliſh'd ſurface of any wrought-glaſs, ſeems not to the naked eye, nor through a *Microſcope*, to be more ſmooth, and leſs porous. And yet, that this hard cloſe body is repleniſh'd with abundance of pores, I think theſe following Experiments will ſufficiently prove.

The firſt is, That if you take ſuch a piece, and for a pretty while boyl it in Turpentine and Oyl of Turpentine, you ſhall find that the ſtone will be all imbu'd with it; and whereas before it look'd more white, but more opacous, now it will look more greaſie, but be much more tranſparent, and if you let it lie but a little while, and then break off a part of it, you ſhall find the unctuous body to have penetrated it to ſuch a determinate depth every way within the ſurface. This may be yet eaſier try'd with a piece of the ſame *Marble*, a little warm'd in the fire, and then a little Pitch or Tarr melted on the top of it; for theſe black bodies, by their inſinuating themſelves into the inviſible pores of the ſtone, ting it with ſo black a hue, that there can be no further doubt of the truth of this aſſertion, that it abounds with ſmall imperceptible pores.

Now, that other bodies will alſo ſink into the pores of *Marble*, beſides *unctuous*, I have try'd, and found, that a very Blue tincture made in

ſpirit of Vrine would very readily and eaſily ſink into it, as would alſo ſeveral tinctures drawn with *ſpirit of Wine.*

Nor is *Marble* the only ſeemingly cloſe ſtone, which by other kinds of Experiments may be found porous; for I have by this kind of Experiment on divers other ſtones found much the ſame effect, and in ſome, indeed much more notable. Other ſtones I have found ſo porous, that with the *Microſcope* I could perceive ſeveral ſmall winding holes, much like Worm-holes, as I have noted in ſome kind of *Purbeck-ſtone*, by looking on the ſurface of a piece newly flaw'd off; for if otherwiſe, the ſurface has been long expos'd to the Air, or has been ſcraped with any tool, thoſe ſmall caverns are fill'd with duſt, and diſappear.

And to confirm this *Conjecture*, yet further, I ſhall here inſert an excellent account, given into the *Royal Society* by that Eminently Learned Phyſician, Doctor *Goddard*, of an Experiment, not leſs inſtructive then curious and accurate, made by himſelf on a very hard and ſeemingly cloſe ſtone call'd *Oculus Mundi*, as I find it preſerv'd in the Records of that Honourable Society.

A ſmall ſtone of the kind, call'd by ſome Authours, *Oculus Mundi*, being dry and cloudy, weigh'd $5\frac{209}{256}$ *Grains.*

The ſame put under water for a night, and ſomewhat more, became tranſparent; and the ſuperficies being wiped dry, weighed $6\frac{3}{256}$ *Grains.*

The difference between theſe two weights, $0\frac{50}{256}$ of a *Grain.*

The ſame Stone kept out of water one Day and becoming cloudy again weighed, $5\frac{225}{256}$ *Graines.*

Which was more then the firſt weight, $0\frac{16}{256}$ of a *Grain.*

The ſame being kept two Days longer weighed, $5\frac{202}{256}$ *Graines.*

Which was leſs then at firſt, $0\frac{7}{256}$ of a *Grain.*

Being kept dry ſomething longer it did not grow ſenſibly lighter.

Being put under water for a night and becoming again tranſparent and wiped dry, the weight was, $6\frac{3}{256}$ *Grains*, the ſame with the firſt after putting in water, and more then the laſt weight after keeping of it dry, $0\frac{57}{256}$ of a *Grain.*

Another Stone of the ſame kind being variegated with milky *white* and *gray* like ſome ſorts of *Agates*, while it lay under water, was alwaies invironed with little Bubbles, ſuch as appear in

water

water a little before boyling, next the ſides of the Veſſel.

There were alſo ſome the like Bubbles on the Surface of the water juſt over it, as if either ſome exhalations came out of it, or that it did excite ſome fermentation in the parts of the water contiguous to it.

There was little ſenſible difference in the tranſparency of this Stone, before the putting under water, and after; To be ſure the milky-*white* parts continued as before, but more difference in weight then in the former. For whereas before the putting into the water the weight was $18\frac{97}{128}$ *Graines.* After it had lyen in about four and twenty hours the weight was $20\frac{27}{128}$ *Graines*, ſo the difference was, $1\frac{58}{128}$ *Graines.*

The ſame Stone was infuſed in the water ſcalding hot, and ſo continued for a while after it was cold, but got no more weight then upon infuſing in the cold, neither was there any ſenſible Difference in the weight both times.

In which Experiment, there are three Obſervables, that ſeem very manifeſtly to prove the porouſneſs of theſe ſeemingly cloſe bodies: the firſt is their acquiring a tranſparency, and loſing their whiteneſs after ſteeping in water, which will ſeem the more ſtrongly to argue it, if what I have already ſaid about the making tranſparent, or clarifying of ſome bodies, as the white powder of beaten Glaſs, and the froth of ſome glutinous tranſparent liquor be well conſider'd; for thereby it will ſeem rational to think that this tranſparency ariſes from the inſinuation of the water (which has much the ſame refraction with ſuch ſtony particles, as may be diſcoverd by Sand view'd with a *Microſcope*) into thoſe pores which were formerly repleat with air (that has a very differing refraction, and conſequently is very reflective) which ſeems to be confirm'd by the ſecond Obſervable, namely, the increaſe of weight after ſteeping, and decreaſe upon drying. And thirdly, ſeem'd yet more ſenſibly confirm'd by the multitude of bubbles in the laſt Experiment.

We find alſo moſt Acid Salts very readily to diſſolve and ſeparate the parts of this body one from another; which is yet a further Argument to confirm the porouſneſs of bodies, and will ſerve as ſuch, to ſhew that even Glaſs alſo has an abundance of pores in it, ſince there are ſeveral liquors, that with long ſtaying in a Glaſs, will ſo *Corrode* and eat into it, as at laſt, to make it pervious to the liquor it contain'd, of which I have ſeen very many Inſtances.

Since therefore we find by other proofs, that many of thoſe bodies

which we think the moſt ſolid ones, and appear ſo to our ſight, have notwithſtanding abundance of thoſe groſſer kind of pores, which will admit ſeveral kinds of liquors into them, why ſhould we not believe that Glaſs, and all other tranſparent bodies abound with them, ſince we have many other arguments, beſides the propagation of light, which ſeem to argue for it?

And whereas it may be objected, that the propagation of light is no argument that there are thoſe atomical pores in glaſs, ſince there are *Hypotheſes* plauſible enough to ſolve thoſe *Phænomena*, by ſuppoſing the pulſe onely to be communicated through the tranſparent body.

To this I anſwer, that that *Hypotheſis* which the induſtrious *Moreanus* has publiſh'd about the ſlower motion of the end of a Ray in a denſer *medium*, then in a more rare and thin, ſeems altogether unſufficient to ſolve abundance of *Phænomena*, of which this is not the leaſt conſiderable, that it is impoſſible from that ſuppoſition, that any colours ſhould be generated from the refraction of the Rays; for ſince by that *Hypotheſis* the *undulating pulſe* is always carried perpendicular, or at right angles with the Ray or Line of direction, it follows, that the ſtroke of the pulſe of light, after it has been once or twice refracted (through a Priſme, for example) muſt affect the eye with the ſame kind of ſtroke as if it had not been refracted at all. Nor will it be enough for a Defendant of that *Hypotheſis*, to ſay, that perhaps it is becauſe the refractions have made the Rays more weak, for if ſo, then two refractions in the two parallel ſides of a *Quadrangular Priſme* would produce colours, but we have no ſuch *Phænomena* produc'd.

There are ſeveral Arguments that I could bring to evince that there are in all tranſparent bodies ſuch atomical pores. And that there is ſuch a fluid body as I am arguing for, which is the *medium*, or Inſtrument, by which the pulſe of Light is convey'd from the *lucid body* to the enlightn'd. But that it being a digreſſion from the Obſervations I was recording, about the Pores of *Kettering Stone*, it would be too much ſuch, if I ſhould protract it too long; and therefore I ſhall proceed to the next *Obſervation*.

Obſerv. XVI. *Of* Charcoal, *or burnt* Vegetables.

CHarcoal, or a Vegetable burnt black, affords an object no leſs pleaſant than inſtructive; for if you take a ſmall round Charcoal, and break it ſhort with your fingers, you may perceive it to break with a very ſmooth and ſleek ſurface, almoſt like the ſurface of black ſealing Wax; this ſurface, if it be look'd on with an ordinary *Microſcope*, does manifeſt abundance of thoſe pores which are alſo viſible to the eye in many kinds of *Wood*, rang'd round the pith, both a in kind of circular order, and a radiant one. Of theſe there are a multitude in the ſubſtance of the Coal, every where almoſt perforating and drilling it from end to end; by means

means of which, be the Coal never so long, you may easily blow through it ; and this you may presently find, by wetting one end of it with Spittle, and blowing at the other.

But this is not all, for besides those many great and conspicuous irregular spots or pores, if a better *Microscope* be made use of, there will appear an infinite company of exceedingly small, and very regular pores, so thick and so orderly set, and so close to one another, that they leave very little room or space between them to be fill'd with a solid body, for the apparent *interstitia*, or separating sides of these pores seem so thin in some places, that the texture of a Honey-comb cannot be more porous. Though this be not every where so, the intercurrent partitions in some places being very much thicker in proportion to the holes.

Most of these small pores seem'd to be pretty round, and were rang'd in rows that radiated from the pith to the bark ; they all of them seem'd to be continued open pores, running the whole length of the Stick ; and that they were all perforated, I try'd by breaking off a very thin sliver of the Coal cross-ways, and then with my *Microscope*, diligently surveying them against the light, for by that means I was able to see quite through them.

These pores were so exceeding small and thick, that in a line of them, $\frac{1}{18}$ part of an Inch long, I found by numbring them no less then 150. small pores ; and therefore in a line of them an Inch long, must be no less then 2700. pores, and in a circular *area* of an Inch diameter, must be about 5725350. of the like pores ; so that a Stick of an Inch Diameter, may containe no less then seven hundred and twenty five thousand, besides 5 Millions of pores, which would, I doubt not, seem even incredible, were not every one left to believe his own eyes. Nay, having since examin'd *Cocus*, *black and green Ebony*, *Lignum Vitæ*, &c. I found, that all these Woods have their pores, abundantly smaller then those of soft light Wood ; in so much, that those of *Guajacum* seem'd not above an eighth part of the bigness of the pores of Beech, but then the *Interstitia* were thicker ; so prodigiously curious are the contrivances, pipes, or sluces by which the *Succus nutritius*, or Juyce of a Vegetable is convey'd from place to place.

This *Observation* seems to afford us the true reason of several *Phænomena* of Coals ; as

First, why they look black ; and for this we need go no further then the *Scheme*, for certainly, a body that has so many pores in it as this is discover'd to have, from each of which no light is reflected, must necessarily look black, especially, when the pores are somewhat bigger in proportion to the intervals then they are cut in the *Scheme*, black being nothing else but a privation of Light, or a want of reflection ; and wheresover this reflecting quality is deficient, there does that part look black, whether it be from a porousness of the body, as in this Instance, or in a deadning and dulling quality, such as I have observ'd in the *Scoria* of Lead, Tin, Silver, Copper, &c.

Next, we may also as plainly see the reason of its shining quality, and that

that is from the even breaking off of the ſtick, the ſolid *interſtitia* having a regular termination or ſurface, and having a pretty ſtrong reflecting quality, the many ſmall reflections become united to the naked eye, and make a very pretty ſhining ſurface.

Thirdly, the reaſon of its hardneſs and brittleneſs ſeems evident, for ſince all the watery or liquid ſubſtance that moiſtn'd and toughn'd thoſe *Interſtitia* of the more ſolid parts, are evaporated and remov'd, that which is left behind becomes of the nature almoſt of a ſtone, which will not at all, or very little, bend without a *divulſion* or *ſolution* of its *continuity*.

It is not my deſign at preſent, to examine the uſe and *Mechaniſme* of theſe parts of Wood, that being more proper to another Enquiry; but rather to hint, that from this Experiment we may learn,

Firſt, what is the cauſe of the blackneſs of many burnt bodies, which we may find to be nothing elſe but this; that the heat of the fire agitating and rarifying the wateriſh, tranſparent, and volatile water that is contain'd in them, by the continuation of that action, does ſo totally expel and drive away all that which before fill'd the pores, and was diſpers'd alſo through the ſolid maſs of it, and thereby caus'd an univerſal kind of tranſparency, that it not onely leaves all the pores empty, but all the *Interſtitia* alſo ſo dry and *opacous*, and perhaps alſo yet further perforated, that that light onely is reflected back which falls upon the very outward edges of the pores, all they that enter into the pores of the body, never returning, but being loſt in it.

Now, that the Charring or coaling of a body is nothing elſe, may be eaſily believ'd by one that ſhall conſider the means of its production, which may be done after this, or any ſuch manner. The body to be charr'd or coal'd, may be put into a *Crucible*, Pot, or any other Veſſel that will endure to be made red-hot in the Fire without breaking, and then cover'd over with Sand, ſo as no part of it be ſuffer'd to be open to the Air, then ſet into a good Fire, and there kept till the Sand has continu'd red hot for a quarter, half, an hour or two, or more, according to the nature and bigneſs of the body to be coal'd or charr'd, then taking it out of the Fire, and letting it ſtand till it be quite cold, the body may be taken out of the Sand well charr'd and cleans'd of its wateriſh parts; but in the taking of it out, care muſt be had that the Sand be very neer cold, for elſe, when it comes into the free air, it will take fire, and readily burn away.

This may be done alſo in any cloſe Veſſel of Glaſs, as a *Retort*, or the like, and the ſeveral fluid ſubſtances that come over may be receiv'd in a fit *Recipient*, which will yet further countenance this *Hypotheſis*: And their manner of charring Wood in great quantity comes much to the ſame thing, namely, an application of a great heat to the body, and preſerving it from the free acceſs of the devouring air; this may be eaſily learn'd from the Hiſtory of Charring of Coal, moſt excellently deſcrib'd and publiſh'd by that moſt accompliſh'd Gentleman, Mr. *John Evelin*, in the 100, 101, 103, pages of his *Sylva*, to which I ſhall therefore refer the curious Reader that deſires a full information of it.

Next

Next, we may learn what part of the Wood it is that is the *combuſtible* matter; for ſince we ſhall find that none, or very little of thoſe fluid ſubſtances that are driven over into the Receiver are *combuſtible*, and that moſt of that which is left behind is ſo, it follows, that the ſolid *interſtitia* of the Wood are the *combuſtible* matter. Further, the reaſon why uncharr'd Wood burns with a greater flame then that which is charr'd, is as evident, becauſe thoſe wateriſh or volatil parts iſſuing out of the fired Wood, every way, not onely ſhatter and open the body, the better for the fire to enter, but iſſuing out in vapours or wind, they become like ſo many little *æolipiles*, or Bellows, whereby they blow and agitate the fir'd part, and conduce to the more ſpeedy and violent conſumption or diſſolution of the body.

Thirdly, from the Experiment of charring of Coals (whereby we ſee that notwithſtanding the great heat, and the duration of it, the ſolid parts of the Wood remain, whileſt they are preſerv'd from the free acceſs of the air undiſſipated) we may learn, that which has not, that I know of, been publiſh'd or hinted, nay, not ſo much as thought of, by any; and that in ſhort is this.

Firſt, *that the Air* in which we live, move, and breath, and which encompaſſes very many, and cheriſhes moſt bodies it encompaſſes, that this Air is the *menſtruum*, or univerſal diſſolvent of all *Sulphureous* bodies.

Secondly, *that this action* it performs not, till the body be firſt ſufficiently heated, as we find requiſite alſo to the diſſolution of many other bodies by ſeveral other *menſtruums*.

Thirdly, *that this action* of diſſolution, produces or generates a very great heat, and that which we call Fire; and this is common alſo to many diſſolutions of other bodies, made by *menſtruums*, of which I could give multitudes of Inſtances.

Fourthly, *that this action* is perform'd with ſo great a violence, and does ſo minutely act, and rapidly agitate the ſmalleſt parts of the *combuſtible* matter, that it produces in the *diaphanous medium* of the Air, the action or pulſe of light, which what it is, I have elſe-where already ſhewn.

Fifthly, *that the diſſolution* of ſulphureous bodies is made by a ſubſtance inherent, and mixt with the Air, that is like, if not the very ſame, with that which is fixt in *Salt-peter*, which by multitudes of Experiments that may be made with *Saltpeter*, will, I think, moſt evidently be demonſtrated.

Sixthly, *that in this diſſolution* of bodies by the Air, a certain part is united and mixt, or diſſolv'd and turn'd into the Air, and made to fly up and down with it in the ſame manner as a *metalline* or other body diſſolv'd into any *menſtruums*, does follow the motions and progreſſes of that *menſtruum* till it be precipitated.

Seventhly, That as there is one part that is diſſoluble by the Air, ſo are there other parts with which the parts of the Air mixing and uniting, do make a *Coagulum*, or *precipitation*, as one may call it, which cauſes it to be ſeparated from the Air, but this *precipitate* is ſo light, and in ſo ſmall and rarify'd or porous cluſters, that it is very volatil, and is eaſily carry'd up by the motion of the Air, though afterwards, when the heat and

agitation

agitation that kept it rarify'd ceases,it easily condenses,and commixt with other indissoluble parts, it sticks and adheres to the next bodies it meets withall; and this is a certain *Salt* that may be extracted out of *Soot.*

Eighthly, that many indissoluble parts being very apt and prompt to be rarify'd, and so, whilest they continue in that heat and agitation, are lighter then the Ambient Air, are thereby thrust and carry'd upwards with great violence, and by that means carry along with them, not onely that *Saline concrete* I mention'd before, but many terrestrial, or indissoluble and irrarefiable parts, nay, many parts also which are dissoluble, but are not suffer'd to stay long enough in a sufficient heat to make them prompt and apt for that action. And therefore we find in *Soot*, not onely a part, that being continued longer in a competent heat, will be dissolv'd by the Air, or take fire and burn; but a part also which is fixt, terrestrial, and irrarefiable.

Ninthly, that as there are these several parts that will rarifie and fly, or be driven up by the heat, so are there many others, that as they are indissoluble by the *aerial menstruum*,so are they of such sluggish and gross parts, that they are not easily rarify'd by heat, and therefore cannot be rais'd by it; the volatility or fixtness of a body seeming to consist only in this, that the one is of a texture, or has component parts that will be easily rarify'd into the form of Air, and the other, that it has such as will not,without much ado,be brought to such a constitution; and this is that part which remains behind in a white body call'd Ashes, which contains a substance,or *Salt*,which Chymists call *Alkali:* what the particular natures of each of these bodies are, I shall not here examine, intending it in another place,but shall rather add that this *Hypothesis* does so exactly agree with all *Phænomena* of Fire, and so genuinely explicate each particular circumstance that I have hitherto observ'd, that it is more then probable, that this cause which I have assign'd is the true adequate, real, and onely cause of those *Phænomena*; And therefore I shall proceed a little further, to shew the nature and use of the Air.

Tenthly,therefore the dissolving parts of the Air are but few,that is,it seems of the nature of those *Saline menstruums*, or spirits, that have very much flegme mixt with the spirits, and therefore a small parcel of it is quickly glutted, and will dissolve no more; and therefore unless some fresh part of this *menstruum* be apply'd to the body to be dissolv'd, the action ceases, and the body leaves to be dissolv'd and to shine, which is the Indication of it, though plac'd or kept in the greatest heat; whereas *Salt-peter* is a *menstruum*, when melted and red-hot, that abounds more with those Dissolvent particles, and therefore as a small quantity of it will dissolve a great sulphureous body, so will the dissolution be very quick and violent.

Therefore in the *Eleventh* place, it is observable, that, as in other solutions, if a copious and quick supply of fresh *menstruum*, though but weak, be poured on, or applied to the dissoluble body, it quickly consumes it: So this *menstruum* of the Air, if by Bellows, or any other such contrivance, it be copiously apply'd to the shining body, is found to dissolve

diſſolve it as ſoon, and as violently as the more ſtrong *menſtruum* of melted *Nitre*.

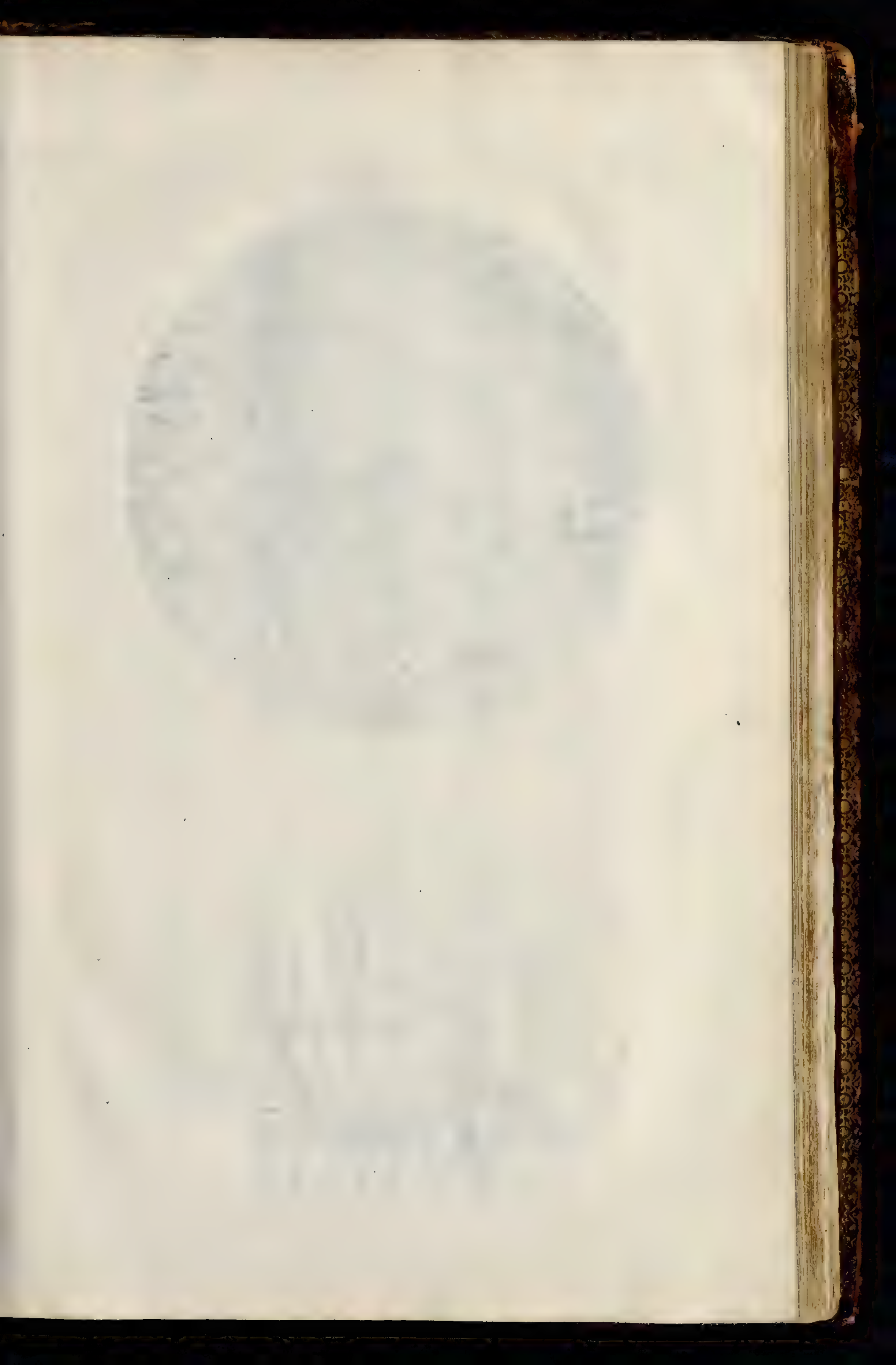
Therefore twelfthly, it ſeems reaſonable to think that there is no ſuch thing as an Element of Fire that ſhould attract or draw up the flame, or towards which the flame ſhould endeavour to aſcend out of a deſire or appetite of uniting with that as its *Homogeneal* primitive and generating Element; but that that ſhining tranſient body which we call *Flame*, is nothing elſe but a mixture of Air, and volatil ſulphureous parts of diſſoluble or combuſtible bodies, which are acting upon each other whilſt they aſcend, that is, flame ſeems to be a mixture of Air, and the combuſtible volatil parts of any body, which parts the encompaſſing Air does diſſolve or work upon, which action, as it does intend the heat of the *aerial* parts of the diſſolvent, ſo does it thereby further rarifie thoſe parts that are acting, or that are very neer them, whereby they growing much lighter then the heavie parts of that *Menſtruum* that are more remote, are thereby protruded and driven upward; and this may be eaſily obſerv'd alſo in diſſolutions made by any other *menſtruum*, eſpecially ſuch as either create heat or bubbles. Now, this action of the *Menſtuum*, or *Air*, on the diſſoluble parts, is made with ſuch violence, or is ſuch, that it imparts ſuch a motion or pulſe to the *diaphanous* parts of the Air, as I have elſewhere ſhewn is requiſite to produce light.

This *Hypotheſis* I have endeavoured to raiſe from an Infinite of Obſervations and Experiments, the proceſs of which would be much too long to be here inſerted, and will perhaps another time afford matter copious enough for a much larger Diſcourſe, the Air being a Subject which (though all the world has hitherto liv'd and breath'd in, and been unconverſant about) has yet been ſo little truly examin'd or explain'd, that a diligent enquirer will be able to find but very little information from what has been (till of late) written of it: But being once well underſtood, it will, I doubt not, inable a man to render an intelligible, nay probable, if not the true reaſon of all the *Phænomena* of Fire, which, as it has been found by Writers and Philoſophers of all Ages a matter of no ſmall difficulty, as may be ſufficiently underſtood by their ſtrange *Hypotheſes*, and unintelligible Solutions of ſome few *Phænomena* of it; ſo will it prove a matter of no ſmall concern and uſe in humane affairs, as I ſhall elſewhere endeavour to manifeſt when I come to ſhew the uſe of the Air in reſpiration, and for the preſervation of the life, nay, for the conſervation and reſtauration of the health and natural conſtitution of mankind as well as all other aereal *animals*, as alſo the uſes of this principle or propriety of the Air in chymical, mechanical, and other operations. In this place I have onely time to hint an *Hypotheſis*, which, if God permit me life and opportunity, I may elſewhere proſecute, improve and publiſh. In the mean time, before I finiſh this Diſcourſe, I muſt not forget to acquaint the Reader, that having had the liberty granted me of making ſome trials on a piece of *Lignum foſſile* ſhewn to the Royal Society, by the eminently Ingenious and Learned Phyſician, Doctor *Ent*, who receiv'd it for a Preſent from the famous *Ingenioſo Cavalliero de Pozzi*, it being one of the faireſt

and beſt pieces of *Lignum foſſile* he had ſeen; Having (I ſay) taken a ſmall piece of this Wood, and examin'd it, I found it to burn in the open Air almoſt like other Wood, and inſteed of a reſinous ſmoak or fume, it yielded a very bituminous one, ſmelling much of that kind of ſent: But that which I chiefly took notice of, was, that cutting off a ſmall piece of it, about the bigneſs of my Thumb, and charring it in a *Crucible* with Sand, after the manner I above preſcrib'd, I found it infinitely to abound with the ſmaller ſort of pores, ſo extreme thick, and ſo regularly perforating the ſubſtance of it long-ways, that breaking it off a-croſs, I found it to look very like an Honey-comb; but as for any of the ſecond, or bigger kind of pores, I could not find that it had any; ſo that it ſeems, whatever were the cauſe of its production, it was not without thoſe ſmall kind of pores which we have onely hitherto found in Vegetable bodies: and comparing them with the pores which I have found in the Charcoals that I by this means made of ſeveral other kinds of Wood, I find it reſemble none ſo much as thoſe of Firr, to which it is not much unlike in grain alſo, and ſeveral other proprieties.

And therefore, what ever is by ſome, who have written of it, and particularly by *Franciſco Stelluto*, who wrote a Treatiſe in *Italian* of that Subject, which was Printed at *Rome*, 1637. affirm'd that it is a certain kind of Clay or Earth, which in tract of time is turn'd into Wood, I rather ſuſpect the quite contrary, that it was at firſt certain great Trees of Fir or Pine, which by ſome Earthquake, or other caſualty, came to be buried under the Earth, and was there, after a long time's reſidence (according to the ſeveral natures of the encompaſſing adjacent parts) either rotted and turn'd into a kind of Clay, or *petrify'd* and turn'd into a kind of Stone, or elſe had its pores fill'd with certain Mineral juices, which being ſtayd in them, and in tract of time coagulated, appear'd, upon cleaving out, like ſmall Metaline Wires, or elſe from ſome flames or ſcorching forms that are the occaſion oftentimes, and uſually accompany Earthquakes, might be blaſted and turn'd into Coal, or elſe from certain *ſubterraneous* fires which are affirm'd by that Authour to abound much about thoſe parts (namely, in a Province of *Italy*, call'd *Umbria*, now the *Dutchie* of *Spoletto*, in the Territory of *Todi*, anciently call'd *Tudor*: and between the two Villages of *Colleſecco* and *Roſaro* not far diſtant from the high-way leading to *Rome*, where it is found in greater quantity then elſewhere) are by reaſon of their being encompaſſed with Earth, and ſo kept cloſe from the diſſolving Air, charr'd and converted into Coal. It would be too long a work to deſcribe the ſeveral kinds of pores which I met withall, and by this means diſcovered in ſeveral other Vegetable bodies; nor is it my preſent deſign to expatiate upon Inſtances of the ſame kind, but rather to give a Specimen of as many kinds as I have had opportunity as yet of obſerving, reſerving the proſecution and enlarging on particulars till a more fit opportunity; and in proſecution of this deſign, I ſhall here add:

Obſerv.



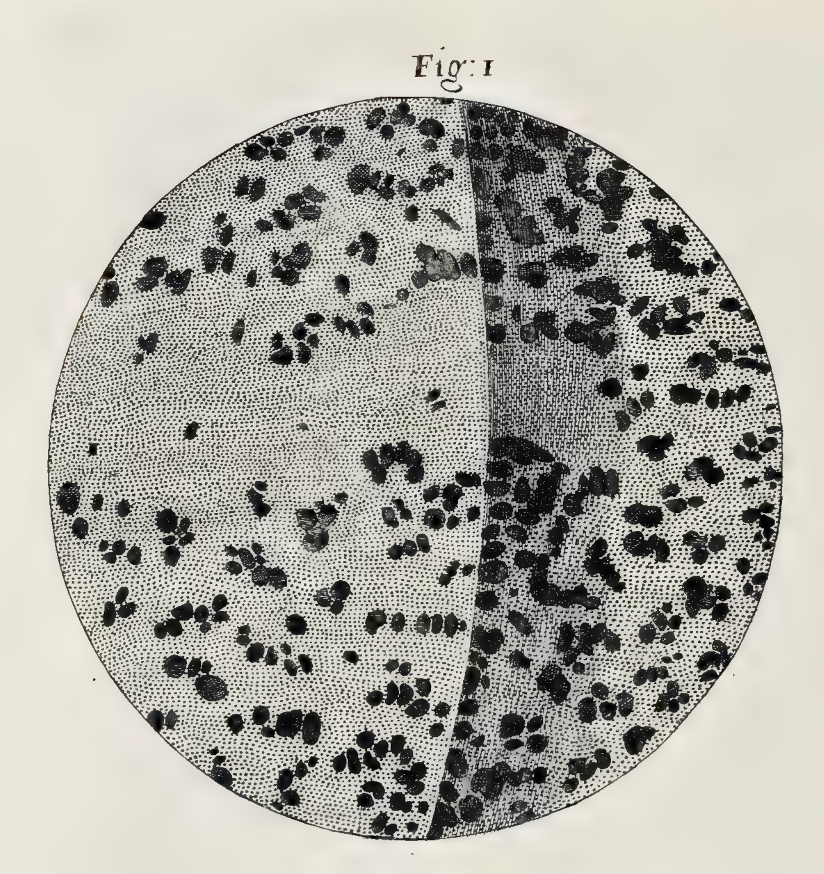


Fig: 2:

Obſerv. XVII. *Of* Petrify'd wood, *and other* Petrify'd bodies.

OF this ſort of ſubſtance, I obſerv'd ſeveral pieces of very differing kinds, both for their outward ſhape, colour, grain, *texture*, hardneſs, *&c.* ſome being brown and rediſh; others gray, like a Hone; others black, and Flint-like: ſome ſoft, like a Slate or Whetſtone, others as hard as a Flint, and as brittle. That which I more particular examin'd, was a piece about the bigneſs of a mans hand, which ſeem'd to have been a part of ſome large tree, that by rottenneſs had been broken off from it before it began to be *petrify'd*.

And indeed, all that I have yet ſeen, ſeem to have been rotten Wood before the petrifaction was begun; and not long ſince, examining and viewing a huge great *Oak*, that ſeem'd with meer age to be rotten as it ſtood, I was very much confirm'd in this opinion; for I found, that the grain, colour, and ſhape of the Wood, was exactly like this *petrify'd* ſubſtance; and with a *Microſcope*, I found, that all thoſe *Microſcopical* pores, which in ſappy or firm and ſound Wood are fill'd with the natural or innate juices of thoſe Vegetables, in this they were all empty, like thoſe of *Vegetables charr'd*; but with this difference, that they ſeem'd much larger then I have ſeen any in *Char-coals*; nay, even then thoſe of Coals made of great blocks of Timber, which are commonly call'd *Old-coals*.

The reaſon of which difference may probably be, that the charring of Vegetables, being an operation quickly perform'd, and whileſt the Wood is ſappy, the more ſolid parts may more eaſily ſhrink together, and contract the pores or *interſtitia* between them, then in the rotten Wood, where that natural juice ſeems onely to be waſh'd away by *adventitious* or unnatural moiſture; and ſo though the natural juice be waſted from between the firm parts, yet thoſe parts are kept aſunder by the *adventitious* moyſtures, and ſo by degrees ſettled in thoſe poſtures.

And this I likewiſe found in the *petrify'd* Wood, that the pores were ſomewat bigger then thoſe of *Charcoal*, each pore being neer upon half as bigg again, but they did not bear that diſproportion which is expreſt in the tenth *Scheme*, between the ſmall ſpecks or pores in the firſt Figure (which repreſenteth the pores of Coal or Wood charr'd) and the black ſpots of the ſecond Figure (which repreſent the like *Microſcopical pores* in the *petrify'd* Wood) for theſe laſt were drawn by a *Microſcope* that magnify'd the object above ſix times more in Diameter then the *Microſcope* by which thoſe pores of Coal were obſerv'd.

Now, though they were a little bigger, yet did they keep the exact figure and order of the pores of Coals and of rotten Wood, which laſt alſo were much of the ſame cize.

The other Obſervations on this *petrify'd* ſubſtance, that a while ſince, by the appointment of the *Royal Society*, I made, and preſented to them an account of, were theſe that follow, which had the honour done them

 by

by the moſt accompliſh'd Mr. *Evelin*, my highly honour'd friend, to be inſerted and publiſhed among thoſe excellent Obſervations wherewith his *Sylva* is repleniſh'd, and would therefore have been here omitted,had not the Figure of them, as they appear'd through the *Microſcope* been before that engraven.

This *Petrify'd* ſubſtance reſembled Wood, in that

First, all the parts of it ſeem'd not at all *diſlocated*, or alter'd from their natural Poſition, whil'ſt they were Wood, but the whole piece retain'd the exact ſhape of Wood, having many of the conſpicuous pores of wood ſtill remaining pores, and ſhewing a manifeſt difference viſible enough between the grain of the Wood and that of the bark, eſpecially when any ſide of it was cut ſmooth and polite; for then it appear'd to have a very lovely grain, like that of ſome curious cloſe Wood.

Next (it reſembled Wood) in that all the ſmaller and (if I may ſo call thoſe which are onely viſible with a good magnifying Glaſs) *Microſcopical* pores of it appear (both when the ſubſtance is cut and poliſh'd *tranſverſly* and *parallel* to the pores of it) perfectly like the *Microſcopical* pores of ſeveral kinds of Wood, eſpecially like and equal to thoſe of ſeveral ſorts of rotten Wood which I have ſince obſerv'd, retaining both the ſhape,poſition and magnitude of ſuch pores. It was differing from Wood:

Firſt, in *weight*, being to common water as $3\frac{1}{4}$ to 1. whereas there are few of our *Engliſh* Woods, that when very dry are found to be full as heavie as water.

Secondly, in *hardneſs*, being very neer as hard as a Flint; and in ſome places of it alſo reſembling the grain of a Flint: and, like it, it would very readily cut Glaſs, and would not without difficulty, eſpecially in ſome parts of it, be ſcratch'd by a black hard Flint: It would alſo as readily ſtrike fire againſt a Steel, or againſt a Flint, as any common Flint.

Thirdly, in the *cloſeneſs* of it, for though all the *Microſcopical* pores of this *petrify'd* ſubſtance were very conſpicuous in one poſition ,yet by altering that poſition of the poliſh'd ſurface to the light, it was alſo manifeſt, that thoſe pores appear'd darker then the reſt of the body, onely becauſe they were fill'd up with a more duſkie ſubſtance, and not becauſe they were hollow.

Fourthly, in its *incombuſtibleneſs*, in that it would not burn in the fire; nay,though I kept it a good while red-hot in the flame of a Lamp, made very *intenſe* by the blaſt of a ſmall Pipe, and a large Charcoal, yet it ſeem'd not at all to have diminiſh'd its extenſion; but only I found it to have chang'd its colour, and to appear of a more dark and duſkie brown colour; nor could I perceive that thoſe parts which ſeem'd to have been Wood at firſt, were any thing waſted, but the parts appear'd as ſolid and cloſe as before. It was further obſervable alſo, that as it did not conſume like Wood, ſo neither did it crack and flie like a Flint, or ſuch like hard Stone, nor was it long before it appear'd red-hot.

Fifthly, in its *diſſolubleneſs*; for putting ſome drops of diſtill'd *Vinegar* upon the Stone, I found it preſently to yield very many Bubbles, juſt like thoſe which may be obſerv'd in ſpirit of *Vinegar* when it corrodes *corals*,

though

though perhaps many of thoſe ſmall Bubbles might proceed from ſome ſmall parcels of Air which were driven out of the pores of this *petrify'd* ſubſtance by the inſinuating liquid *menſtruum.*

Sixthly, in its *rigidneſs* and *friability*, being not at all flexible but brittle like a Flint, inſomuch that I could with one knock of a Hammer break off a piece of it, and with a few more, reduce that into a pretty fine powder.

Seventhly, it ſeem'd alſo very differing from Wood to the *touch, feeling* more cold then Wood uſually does, and much like other cloſe ſtones and Minerals.

The Reaſons of all which *Phænomena* ſeem to be,

That this *petrify'd* Wood having lain in ſome place where it was well ſoak'd with *petrifying* water (that is, ſuch a water as is well *impregnated* with ſtony and earthy particles) did by degrees ſeparate, either by ſtraining and *filtration*, or perhaps, by *precipitation*, *coheſion* or *coagulation*, abundance of ſtony particles from the permeating water, which ſtony particles, being by means of the fluid *vehicle* convey'd, not onely into the *Microſcopical* pores, and ſo perfectly ſtoping them up, but alſo into the pores or *interſtitia*, which may, perhaps, be even in the texture or *Schematiſme* of that part of the Wood, which, through the *Microſcope*, appears moſt ſolid, do thereby ſo augment the weight of the Wood, as to make it above three times heavier then water, and perhaps, ſix times as heavie as it was when Wood.

Next, they thereby ſo lock up and fetter the parts of the Wood, that the fire cannot eaſily make them flie away, but the action of the fire upon them is onely able to *Char* thoſe parts, as it were, like a piece of Wood, if it be clos'd very faſt up in Clay, and kept a good while red-hot in the fire, will by the heat of the fire be charr'd and not conſum'd, which may, perhaps, alſo be ſomewhat of the cauſe, why the *petrify'd* ſubſtance appear'd of a dark brown colour after it had been burnt.

By this *intruſion* of the *petrifying* particles, this ſubſtance alſo becomes hard and *friable*; for the ſmaller pores of the Wood being perfectly wedg'd, and ſtuft up with thoſe ſtony particles, the ſmall parts of the Wood have no places or pores into which they may ſlide upon bending, and conſequently little or no flexion or yielding at all can be caus'd in ſuch a ſubſtance.

The remaining particles likewiſe of the Wood among the ſtony particles, may keep them from cracking and flying when put into the fire, as they are very apt to do in a Flint.

Nor is Wood the onely ſubſtance that may by this kind of *tranſmutation* be chang'd into ſtone; for I my ſelf have ſeen and examin'd very many kinds of ſubſtances, and among very credible Authours, we may meet with Hiſtories of ſuch *Metamorphoſes* wrought almoſt on all kind of ſubſtances, both *Vegetable* and *Animal*, which Hiſtories, it is not my buſineſ at preſent, either to relate, or *epitomiſe*, but only to ſet down ſome Obſervation I lately made on ſeveral kind of *petrify'd* Shels, found about *Keinſham*, which lies within four or five miles of *Briſtol*, which are commonly call'd *Serpentine-ſtones.*

Exami-

Examining ſeveral of theſe very curiouſly figur'd bodies (which are commonly thought to be Stones form'd by ſome extraordinary *Plaſtick virtue latent* in the Earth it ſelf) I took notice of theſe particulars:

Firſt, that theſe figured bodies, or ſtones, were of very differing ſubſtances, as to hardneſs: ſome of Clay, ſome Marle, ſome ſoft Stone, almoſt of the hardneſs of thoſe ſoft ſtones which Maſons call Fire-ſtone, others as hard as Portland ſtone, others as hard as Marble, and ſome as hard a a Flint or Cryſtal.

Next, they were of very differing ſubſtances as to tranſparency and colour; ſome white, ſome almoſt black, ſome brown, ſome Metalline, or like Marchaſites; ſome tranſparent like white Marble, others like flaw'd Cryſtal, ſome gray, ſome of divers colours; ſome radiated like theſe long *petrify'd drops*, which are commonly found at the *Peak*, and in other *ſubterraneous caverns*, which have a kind of pith in the middle.

Thirdly, that they were very different as to the manner of their outward figuration; for ſome of them ſeem'd to have been the ſubſtance that had fill'd the Shell of ſome kind of Shel-fiſh; others, to have been the ſubſtance that had contain'd or enwrapp'd one of thoſe Shels, on both which, the perfect impreſſion either of the inſide or outſide of ſuch Shells ſeem'd to be left, but for the moſt part, thoſe impreſſions ſeem'd to be made by an imperfect or broken Shell, the great end or mouth of the Shell being always wanting, and oftentimes the little end, and ſometimes half, and in ſome there were impreſſions, juſt as if there had been holes broken in the figurating, imprinting or moulding Shell; ſome of them ſeem'd to be made by ſuch a Shell very much bruſed or flaw'd, inſomuch that one would verily have thought that very figur'd ſtone had been broken or bruſed whilſt a gelly, as 'twere, and ſo hardned, but within in the grain of the ſtone, there appear'd not the leaſt ſign of any ſuch bruſe or breaking, but onely on the very uttermoſt ſuperficies.

Fourthly, they were very different, as to their outward covering, ſome having the perfect Shell, both in figure, colour, and ſubſtance, ſticking on upon its ſurface, and adhering to it, but might very eaſily be ſeparated from it, and like other common *Cockle* or *Scolop-ſhels*, which ſome of them moſt accurately reſembled, were very diſſoluble in common *Vinegar*, others of them, eſpecially thoſe *Serpentine*, or *Helical ſtones* were cover'd or retained the ſhining or Pearl-colour'd ſubſtance of the inſide of a Shel, which ſubſtance, on ſome parts of them, was exceeding thin, and might very eaſily be rubbed off; on other parts it was pretty thick, and retained a white coat, or flaky ſubſtance on the top, juſt like the outſides of ſuch Shells; ſome of them had very large pieces of the Shell very plainly ſticking on to them, which were eaſily to be broken or flaked off by degrees: they likewiſe, ſome of them retain'd all along the ſurface of them very pretty kind of *ſutures*, ſuch as are obſerv'd in the ſkulls of ſeveral kinds of living creatures, which *ſutures* were moſt curiouſly ſhap'd in the manner of leaves, and every one of them in the ſame Shell, exactly one like another, which I was able to diſcover plainly enough with my naked eye, but more perfectly and diſtinctly with my *Microſcope*; all

theſe

these *sutures*, by breaking some of these stones, I found to be the *termini*, or boundings of certain *diaphragms*, or partitions, which seem'd to divide the cavity of the Shell into a multitude of very proportionate and regular *cells* or *caverns*, these *Diaphragms*, in many of them, I found very perfect and compleat, of a very distinct substance from that which fill'd the cavities, and exactly of the same kind with that which covered the outside, being for the most part whitish, or *mother-of-pearl* colour'd.

As for the cavities between those *Diaphragms*, I found some of them fill'd with Marle, and others with several kinds of stones, others, for the most part hollow, onely the whole cavity was usually covered over with a kind of *tartareous petrify'd* substance, which stuck about the sides, and was there shot into very curious regular Figures, just as *Tartar*, or other dissolv'd Salts are observ'd to stick and *crystallize* about the sides of the containing Vessels; or like those little *Diamants* which I before observed to have covered the vaulted cavity of a Flint; others had these cavities all lin'd with a kind of *metalline* or *marchasite-like* substance, which with a *Microscope* I could as plainly see most curiously and regularly figured, as I had done those in a Flint.

From all which, and several other particulars which I observ'd, I cannot but think, that all these, and most other kinds of stony bodies which are found thus strangely figured, do owe their formation and figuration, not to any kind of *Plastick virtue* inherent in the earth, but to the Shells of certain Shel-fishes, which, either by some Deluge, Inundation, Earthquake, or some such other means, came to be thrown to that place, and there to be fill'd with some kind of Mudd or Clay, or *petrifying* Water, or some other substance, which in tract of time has been settled together and hardned in those shelly moulds into those shaped substances we now find them; that the great and thin end of these Shells by that Earthquake, or what ever other extraordinay cause it was that brought them thither, was broken off; and that many others were otherwise broken, bruised and disfigured; that these Shells which are thus *spiralled* and separated with *Diaphragmes*, were some kind of *Nautili* or *Porcelane shells*; and that others were shells of *Cockles*, *Muscles*, *Periwincles*, *Scolops*, &c. of various sorts; that these Shells in many, from the particular nature of the containing or enclos'd Earth, or some other cause, have in tract of time rotted and mouldred away, and onely left their impressions, both on the containing and contained substances; and so left them pretty loose one within another, so that they may be easily separated by a knock or two of a Hammer. That others of these Shells, according to the nature of the substances adjacent to them, have, by a long continuance in that posture, been *petrify'd* and turn'd into the nature of stone, just as I even now observ'd several sorts of Wood to be. That oftentimes the Shell may be found with one kind of substance within, and quite another without, having, perhaps, been fill'd in one place, and afterwards translated to another, which I have very frequently observ'd in *Cockle*, *Muscle*, *Periwincle*, and other shells, which I have found by the Sea side. Nay, further, that some parts of the same Shell may be fill'd in one place, and some

ſome other caverns in another, and others in a third, or a fourth, or a fifth place, for ſo many differing ſubſtances have I found in one of theſe *petrify'd* Shells, and perhaps all theſe differing from the encompaſſing earth or ſtone; the means how all which varieties may be caus'd, I think, will not be difficult to conceive, to any one that has taken notice of thoſe Shells, which are commonly found on the Sea ſhore: And he that ſhall throughly examine ſeveral kinds of ſuch curiouſly form'd ſtones, will (I am very apt to think) find reaſon to ſuppoſe their generation or formation to be aſcribable to ſome ſuch accidents as I have mention'd, and not to any *Plaſtick virtue*: For it ſeems to me quite contrary to the infinite prudence of Nature, which is obſervable in all its works and productions, to deſign every thing to a determinate end, and for the attaining of that end, makes uſe of ſuch ways as are (as farr as the knowledge of man has yet been able to reach) altogether conſonant, and moſt agreeable to man's reaſon, and of no way or means that does contradict, or is contrary to humane Ratiocination; whence it has a long time been a general obſervation and *maxime*, that *Nature does nothing in vain*; It ſeems, I ſay, contrary to that great Wiſdom of Nature, that theſe prettily ſhap'd bodies ſhould have all thoſe curious Figures and contrivances (which many of them are adorn'd and contriv'd with) generated or wrought by a *Plaſtick virtue*, for no higher end then onely to exhibite ſuch a form; which he that ſhall throughly conſider all the circumſtances of ſuch kind of Figur'd bodies, will, I think, have great reaſon to believe, though, I confeſs, one cannot preſently be able to find out what Nature's deſigns are. It were therefore very deſirable, that a good collection of ſuch kind of figur'd ſtones were collected; and as many particulars, circumſtances, and informations collected with them as could be obtained, that from ſuch a Hiſtory of Obſervations well rang'd, examin'd and digeſted, the true original or production of all thoſe kinds of ſtones might be perfectly and ſurely known; ſuch as are *Thunder-ſtones*, *Lapides Stellares*, *Lapides Judaici*, and multitudes of other, whereof mention is made in *Aldrovandus Wormius*, and other Writers of Minerals.

Obſerv. XVIII. *Of the* Schematiſme *or* Texture *of* Cork, *and of the Cells and Pores of ſome other ſuch frothy Bodies.*

I Took a good clear piece of Cork, and with a Pen-knife ſharpen'd as keen as a Razor, I cut a piece of it off, and thereby left the ſurface of it exceeding ſmooth, then examining it very diligently with a *Microſcope*, me thought I could perceive it to appear a little porous; but I could not ſo plainly diſtinguiſh them, as to be ſure that they were pores, much leſs what Figure they were of: But judging from the lightneſs and yielding quality of the Cork, that certainly the texture could not be ſo curious,

curious, but that possibly, if I could use some further diligence, I might find it to be discernable with a *Microscope*, I with the same sharp Pen-knife, cut off from the former smooth surface an exceeding thin piece of it, and placing it on a black object Plate, because it was it self a white body, and casting the light on it with a deep *plano-convex Glass*, I could exceeding plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular; yet it was not unlike a Honey-comb in these particulars.

First, in that it had a very little solid substance, in comparison of the empty cavity that was contain'd between, as does more manifestly appear by the Figure A and B of the XI. *Scheme*, for the *Interstitia*, or walls (as I may so call them) or partitions of those pores were neer as thin in proportion to their pores, as those thin films of Wax in a Honey-comb (which enclose and constitute the *sexangular cells*) are to theirs.

Next, in that these pores, or cells, were not very deep, but consisted of a great many little Boxes, separated out of one continued long pore, by certain *Diaphragms*, as is visible by the Figure B, which represents a sight of those pores split the long-ways.

I no sooner discern'd these (which were indeed the first *microscopical* pores I ever saw, and perhaps, that were ever seen, for I had not met with any Writer or Person, that had made any mention of them before this) but me thought I had with the discovery of them, presently hinted to me the true and intelligible reason of all the *Phænomena* of Cork; As,

First, if I enquir'd why it was so exceeding light a body? my *Microscope* could presently inform me that here was the same reason evident that there is found for the lightness of froth, an empty Honey-comb, Wool, a Spunge, a Pumice-stone, or the like; namely, a very small quantity of a solid body, extended into exceeding large dimensions.

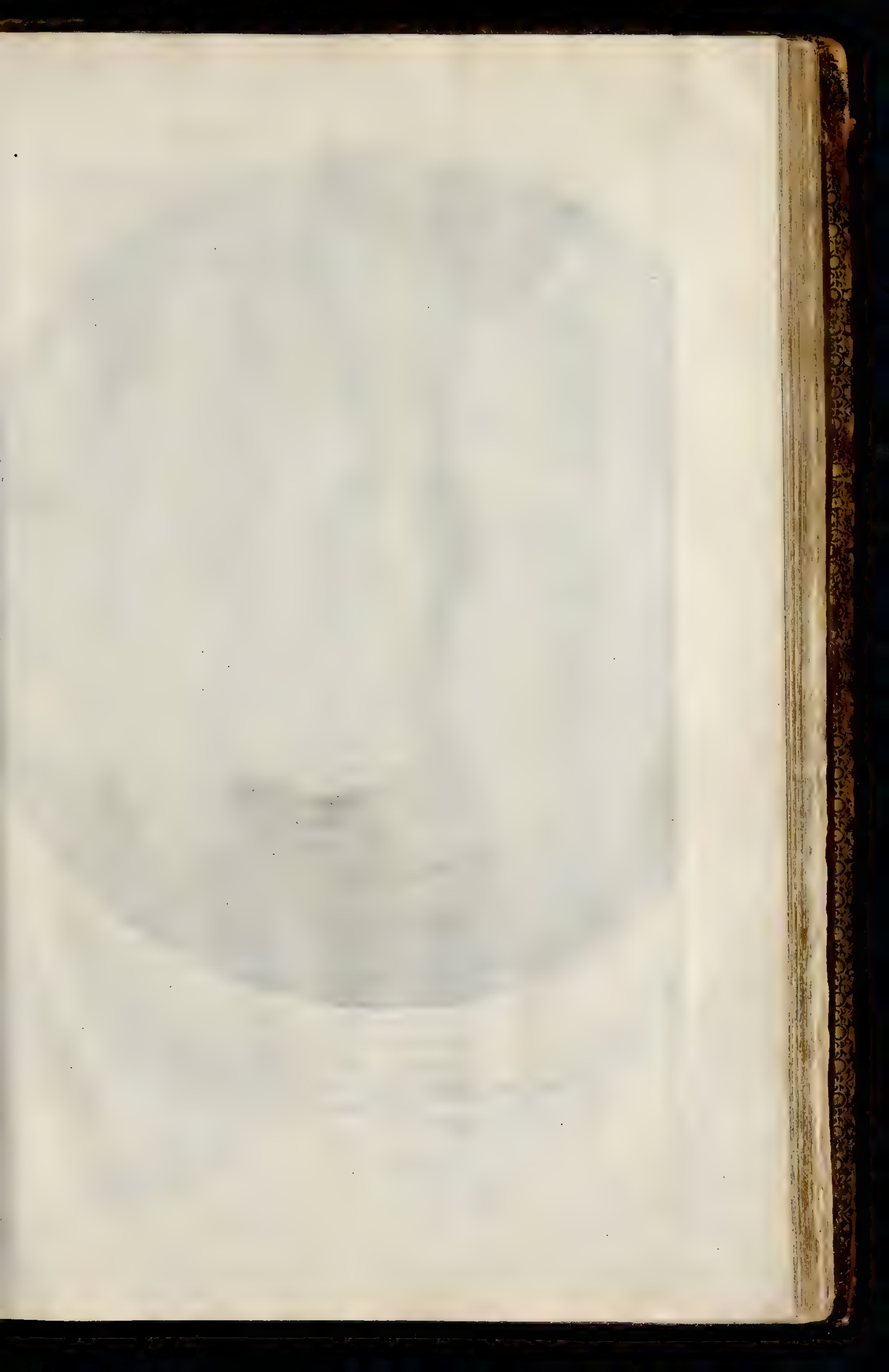
Next, it seem'd nothing more difficult to give an intelligible reason, why Cork is a body so very unapt to suck and drink in Water, and consequently preserves it self, floating on the top of Water, though left on it never so long: and why it is able to stop and hold air in a Bottle, though it be there very much condens'd and consequently presses very strongly to get a passage out, without suffering the least bubble to pass through its substance. For, as to the first, since our *Microscope* informs us that the substance of Cork is altogether fill'd with Air, and that that Air is perfectly enclosed in little Boxes or Cells distinct from one another. It seems very plain, why neither the Water, nor any other Air can easily insinuate it self into them, since there is already within them an *intus existens*, and consequently, why the pieces of Cork become so good floats for Nets, and stopples for Viols, or other close Vessels.

And thirdly, if we enquire why Cork has such a springiness and swelling nature whem compress'd? and how it comes to suffer so great a compression, or seeming penetration of dimensions, so as to be made a substance as heavie again and more, bulk for bulk, as it was before compression, and yet suffer'd to return, is found to extend it self again into the same space? Our *Microscope* will easily inform us, that the whole mass

consists of an infinite company of small Boxes or Bladders of Air, which is a substance of a springy nature, and that will suffer a considerable condensation (as I have several times found by divers trials, by which I have most evidently condens'd it into less then a twentieth part of its usual dimensions neer the Earth, and that with no other strength then that of my hands without any kind of forcing Engine,such as Racks,Leavers,Wheels, Pullies, or the like, but this onely by and by) and besides, it seems very probable that those very films or sides of the pores,have in them a springing quality, as almost all other kind of Vegetable substances have, so as to help to restore themselves to their former position.

And could we so easily and certainly discover the *Schematisme* and *Texture* even of these films,and of several other bodies,as we can these of Cork; there seems no probable reason to the contrary, but that we might as readily render the true reason of all their *Phænomena*; as namely,what were the cause of the springiness, and toughness of some, both as to their flexibility and restitution. What, of the friability or brittleness of some others, and the like; but till such time as our *Microscope*, or some other means,enable us to discover the true *Schematism* and *Texture* of all kinds of bodies, we must grope, as it were, in the dark, and onely ghess at the true reasons of things by similitudes and comparisons.

But, to return to our Observation. I told several lines of these pores, and found that there were usually about threescore of these small Cells placed end-ways in the eighteenth part of an Inch in length,whence I concluded there must be neer eleven hundred of them, or somewhat more then a thousand in the length of an Inch, and therefore in a square Inch above a Million, or 1166400. and in a Cubick Inch,above twelve hundred Millions,or 1259712000. a thing almost incredible, did not our *Microscope* assure us of it by ocular demonstration; nay, did it not discover to us the pores of a body, which were they *diaphragm'd*,like those of Cork, would afford us in one Cubick Inch, more then ten times as many little Cells, as is evident in several charr'd Vegetables; so prodigiously curious are the works of Nature, that even these conspicuous pores of bodies, which seem to be the channels or pipes through which the *Succus nutritius*, or natural juices of Vegetables are convey'd, and seem to correspond to the veins, arteries and other Vessels in sensible creatures, that these pores I say, which seem to be the Vessels of nutrition to the vastest body in the World, are yet so exceeding small, that the *Atoms* which *Epicurus* fancy'd would go neer to prove too bigg to enter them, much more to constitute a fluid body in them.And how infinitely smaller then must be the Vessels of a Mite, or the pores of one of those little Vegetables I have discovered to grow on the back-side of a Rose-leaf, and shall anon more fully describe, whose bulk is many millions of times less then the bulk of the small shrub it grows on; and even that shrub, many millions of times less in bulk then several trees (that have heretofore grown in *England*, and are this day flourishing in other hotter Climates, as we are very credibly inform'd) if at least the pores of this small Vegetable should keep any such proportion to the body of it, as we have found these pores



Schem: XI.



of other Vegetables to do to their bulk. But of these pores I have said more elsewhere.

To proceed then, Cork seems to be by the transverse constitution of the pores, a kind of *Fungus* or Mushrome, for the pores lie like so many Rays tending from the center, or pith of the tree, outwards; so that if you cut off a piece from a board of Cork transversly, to the flat of it, you will, as it were, split the pores, and they will appear just as they are express'd in the Figure B of the XI. *Scheme*. But if you shave off a very thin piece from this board, parallel to the plain of it, you will cut all the pores transversly, and they will appear almost as they are express'd in the Figure A, save onely the solid *Interstitia* will not appear so thick as they are there represented.

So that Cork seems to suck its nourishment from the subjacent bark of the Tree immediately, and to be a kind of excrescence, or a substance distinct from the substances of the entire Tree, something *analogus* to the Mushrome, or Moss on other Trees, or to the hairs on Animals. And having enquir'd into the History of Cork, I find it reckoned as an excrescency of the bark of a certain Tree, which is distinct from the two barks that lie within it, which are common also to other trees; That 'tis some time before the Cork that covers the young and tender sprouts comes to be discernable; That it cracks, flaws, and cleaves into many great chaps, the bark underneath remaining entire; That it may be separated and remov'd from the Tree, and yet the two under-barks (such as are also common to that with other Trees) not at all injur'd, but rather helped and freed from an external injury. Thus *Jonstonus* in *Dendrologia*, speaking *de Subere*, says, *Arbor est procera, Lignum est robustum, dempto cortice in aquis non fluitat, Cortice in orbem detracto juvatur, crascescens enim præstringit & strangulat, intra triennium iterum repletur: Caudex ubi adolescit crassus, cortex superior densus carnosus, duos digitos crassus, scaber, rimosus, & qui nisi detrahatur dehiscit, alioque subnascente expellitur, interior qui subest novellus ita rubet ut arbor minio picta videatur.* Which Histories, if well consider'd, and the tree, substance, and manner of growing, if well examin'd, would, I am very apt to believe, much confirm this my conjecture about the origination of Cork.

Nor is this kind of Texture peculiar to Cork onely; for upon examination with my *Microscope*, I have found that the pith of an Elder, or almost any other Tree, the inner pulp or pith of the Cany hollow stalks of several other Vegetables: as of Fennel, Carrets, Daucus, Bur-docks, Teasels, Fearn, some kinds of Reeds, *&c.* have much such a kind of *Schematisme*, as I have lately shewn that of Cork, save onely that here the pores are rang'd the long-ways, or the same ways with the length of the Cane, whereas in Cork they are transverse.

The pith also that fills that part of the stalk of a Feather that is above the Quil, has much such a kind of texture, save onely that which way soever I set this light substance, the pores seem'd to be cut transversly; so that I ghess this pith which fills the Feather, not to consist of abundance of long pores separated with Diaphragms, as Cork does, but to be a kind

of ſolid or hardned froth,or a *congeries* of very ſmall bubbles conſolidated in that form,into a pretty ſtiff as well as tough concrete,and that each Cavern, Bubble, or Cell, is diſtinctly ſeparate from any of the reſt, without any kind of hole in the encompaſſing films, ſo that I could no more blow through a piece of this kinde of ſubſtance,then I could through a piece of Cork, or the ſound pith of an Elder.

But though I could not with my *Microſcope*, nor with my breath, nor any other way I have yet try'd, diſcover a paſſage out of one of thoſe cavities into another, yet I cannot thence conclude, that therefore there are none ſuch, by which the *Succus nutritius*, or appropriate juices of Vegetables, may paſs through them; for, in ſeveral of thoſe Vegetables, whil'ſt green, I have with my *Microſcope*, plainly enough diſcover'd theſe Cells or Poles fill'd with juices, and by degrees ſweating them out: as I have alſo obſerved in green Wood all thoſe long *Microſcopical* pores which appear in Charcoal perfectly empty of any thing but Air.

Now, though I have with great diligence endeavoured to find whether there be any ſuch thing in thoſe *Microſcopical* pores of Wood or Piths, as the *Valves* in the heart,veins,and other paſſages of Animals,that open and give paſſage to the contain'd fluid juices one way, and ſhut themſelves,and impede the paſſage of ſuch liquors back again,yet have I not hitherto been able to ſay any thing poſitive in it; though,me thinks, it ſeems very probable,that Nature has in theſe paſſages,as well as in thoſe of Animal bodies,very many appropriated Inſtruments and contrivances, whereby to bring her deſigns and end to paſs,which 'tis not improbable, but that ſome diligent Obſerver, if help'd with better *Microſcopes*, may in time detect.

And that this may be ſo, ſeems with great probability to be argued from the ſtrange *Phænomena* of ſenſitive Plants, wherein Nature ſeems to perform ſeveral Animal actions with the ſame *Schematiſm* or *Orginization* that is common to all Vegetables, as may appear by ſome no leſs inſtructive then curious Obſervations that were made by divers Eminent Members of the *Royal Society* on ſome of theſe kind of Plants,whereof an account was delivered in to them by the moſt Ingenious and Excellent *Phyſician*, Doctor *Clark*, which, having that liberty granted me by that moſt Illuſtrious Society, I have hereunto adjoyn'd.

Obſervations on the Humble *and* Senſible Plants *in* Mr. Chiffin's *Garden in Saint* James's *Park*, *made* Auguſt *the* 9th, 1661. *Preſent*, *the* Lord *Brouncker*, Sr. *Robert Moray*, Dr. *Wilkins*, Mr. *Evelin*, Dr. *Henſhaw*, *and* Dr. *Clark*.

There are four Plants, two of which are little ſhrub Plants, with a little ſhort ſtock, about an Inch above the ground, from whence are ſpread ſeveral ſticky branches, round, ſtreight, and

ſmooth,

ſmooth in the diſtances between the Sprouts, but juſt under the Sprouts there are two ſharp thorny prickles, broad in the letting on, as in the Bramble, one juſt under the Sprout, the other on the oppoſite ſide of the branch.

The diſtances betwixt the Sprouts are uſually ſomething more then an Inch, and many upon a Branch, according to its length, and they grew ſo, that if the lower Sprout be on the left ſide of the Branch, the next above is on the right, and ſo to the end, not ſprouting by pairs.

See Schem. 11. Fig. 2.

At the end of each Sprout are generally four ſprigs, two at the Extremity, and one on each ſide, juſt under it. At the firſt ſprouting of theſe from the Branch to the Sprig where the leaves grow, they are full of little ſhort white hairs, which wear off as the leaves grow, and then they are ſmooth as the Branch.

Upon each of theſe ſprigs, are, for the moſt part, eleven pair of leaves, neatly ſet into the uppermoſt part of the little ſprig, exactly one againſt another, as it were in little *articulations*, ſuch as Anatomiſts call *Enarthroſis*, where the round head of a Bone is received into another fitted for its motion; and ſtanding very fitly to ſhut themſelves and touch, the pairs juſt above them cloſing ſomewhat upon them, as in the ſhut ſprig; ſo is the little round *Pedunculus* of this leaf fitted into a little cavity of the ſprig, viſible to the eye in a ſprig new pluck'd, or in a ſprig withered on the Branch, from which the leaves eaſily fall by touching.

The leaf being almoſt an oblong ſquare, and ſet into the *Pedunculus*, at one of the lower corners, receiveth from that not onely a *Spine*, as I may call it, which, paſſing through the leaf, divides it ſo length-ways that the outer-ſide is broader then the inner next the ſprig, but little *fibres* paſſing obliquely towards the oppoſite broader ſide, ſeem to make it here a little muſcular, and fitted to move the whole leaf, which, together with the whole ſprig, are ſet full with little ſhort whitiſh hairs.

One

One of these Plants, whose branch seem'd to be older and more grown then the other, onely the tender Sprouts of it, after the leaves are shut, fall and hang down; of the other, the whole branches fall to the ground, if the Sun shine very warm, upon the first taking off the Glass, which I therefore call the *humble Plant*.

The other two, which do never fall, nor do any of their branches flagg and hang down, shut not their leaves, but upon somewhat a hard stroke; the stalks seem to grow up from a root, and appear more *herbaceous*, they are round and smooth, without any prickle, the Sprouts from them have several pairs of sprigs, with much less leaves then the other on them, and have on each sprig generally seventeen pair.

Upon touching any of the sprigs with leaves on, all the leaves on that sprig contracting themselves by pairs, joyned their upper superficies close together.

Upon the dropping a drop of *Aqua fortis* on the sprig betwixt the leaves, *f f* all the leaves above shut presently, those below by pairs successively after, and by the lower leaves of the other branches, *l l*, *k k*, &c. and so every pair successively, with some little distance of time betwixt, to the top of each sprig, and so they continu'd shut all the time we were there. But I returning the next day, and several days since, found all the leaves dilated again on two of the sprigs; but from *f f*, where the *Aqua fortis* had dropped upwards, dead and withered; but those below on the same sprig, green, and closing upon the touch, and are so at this day, *August* 14.

With a pair of Scissers, as suddenly as it could be done, one of the leaves *b b* was clipped off in the middle, upon which that pair, and the pair above, closed presently, after a little interval, *d d*, then *e e*, and so the rest of the pairs, to the bottom of the sprig, and then the motion began in the lower pairs, *l l*, on the other sprigs, and so shut them by pairs upwards, though not with such distinct distances.

Under

Under a pretty large branch with its ſprigs on, there lying a large Shell betwixt two and three Inches below it, there was rubbed on a ſtrong ſented oyl, after a little time all the leaves on that ſprig were ſhut, and ſo they continued all the time of our ſtay there,but at my returne the next day, I found the poſition of the Shell alter'd, and the leaves expanded as before, and cloſing upon the touch.

Upon the application of the Sun-beams by a Burning-glaſs, the more *humble Plant* fell, the other ſhut their leaves.

We could not ſo apply the ſmoak of *Sulpher*, as to have any viſible effect from that, at two or three times trial; but on another trial,the ſmoak touching the leaves,it ſucceeded.

The *humble Plant* fell upon taking off the Glaſs wherewith it was covered.

Cutting off one of the little Sprouts, two or three drops of liquor were thruſt out of the part from whence that was cut,very cleer, and pellucid, of a bright greeniſh colour, taſting at firſt a little bitteriſh,but after leaving a licoriſh-like taſte in my mouth.

Since,going two or three times when it was cold, I took the Glaſſes from the more *humble Plant*,and it did not fall as formerly, but ſhut its leaves onely. But coming afterwards, when the Sun ſhone very warm, as ſoon as it was taken off, it fell as before.

Since I pluck'd off another ſprig, whoſe leaves were all ſhut, and had been ſo ſome time, thinking to obſerve the liquor ſhould come from that I had broken off, but finding none, though with preſſing,to come, I, as dexterouſly as I could, pull'd off one whoſe leaves were expanded, and then had upon the ſhutting of the leaves, a little of the mention'd liquor, from the end of the ſprig I had broken from the Plant. And this twice ſucceſſively, as often almoſt as I durſt rob the Plant.

But my curioſity carrying me yet further, I cut off one of the harder branches of the ſtronger Plant, and there came of the

liquor, both from that I had cut, and that I had cut it from, without preſſure.

Which made me think, that the motion of this Plant upon touching, might be from this, that there being a conſtant *intercourſe* betwixt every part of this Plant and its root,either by a *circulation* of this liquor,or a conſtant preſſing of the ſubtiler parts of it to every extremity of the Plant. Upon every preſſure,from whatſoever it proceeds, greater then that which keeps it up, the ſubtile parts of this liquor are thruſt downwards, towards its *articulations* of the leaves, where, not having room preſently to get into the ſprig,the little round *pedunculus*, from whence the *Spine* and thoſe oblique *Fibres* I mention'd riſe, being dilated, the *Spine* and *Fibres* (being continued from it) muſt be contracted and ſhortned, and ſo draw the leaf upwards to joyn with its fellow in the ſame condition with it ſelf, where, being cloſed, they are held together by the implications of the little whitiſh hair, as well as by the ſtill retreating liquor, which diſtending the *Fibres* that are continued lower to the branch and root, ſhorten them above ; and when the liquor is ſo much forced from the Sprout, whoſe *Fibres* are yet tender, and not able to ſupport themſelves, but by that tenſneſs which the liquor filling their *interſtices* gives them, the Sprout hangs and flags.

But, perhaps, he that had the ability and leiſure to give you the exact *Anatomy* of this pretty Plant, to ſhew you its *Fibres*, and viſible *Canales*, through which this fine liquor circulateth, or is moved, and had the faculty of better and more copiouſly expreſſing his Obſervations and conceptions, ſuch a one would eaſily from the motion of this liquor, ſolve all the *Phænomena*, and would not fear to affirm, that it is no obſcure ſenſation this Plant hath. But I have ſaid too much, I humbly ſubmit, and am ready to ſtand corrected.

I have not yet made ſo full and ſatisfactory Obſervations as I deſire on this Plant, which ſeems to be a Subject that will afford abundance of information.

information. But as farr as I have had opportunity to examine it,I have discovered with my *Microscope* very curious structures and contrivances; but designing much more accurate examinations and trials,both with my *Microscope*, and otherwise, as soon as the season will permit, I shall not till then add any thing of what I have already taken notice of; but as farr as I have yet observ'd,I judge the motion of it to proceed from causes very differing from those by which Gut-strings,or Lute-strings,the beard of a wilde *Oat*, or the beard of the Seeds of *Geranium*, *Moscatum*, or *Musk-grass* and other of kinds of *Cranes-bill*,move themselves. Of which I shall add more in the subsequent Observations on those bodies.

Observ. XIX. *Of a* Plant *growing in the blighted or yellow specks of* Damask-rose-leaves, Bramble-leaves, *and some other kind of leaves.*

I Have for several years together, in the Moneths of *June*, *July*, *August*, and *September* (when any of the green leaves of *Roses* begin to dry and grow yellow) observ'd many of them, especially the leaves of the old shrubs of *Damask-Roses*, all bespecked with yellow stains, and the under-sides just against them, to have little yellow hillocks of a gummous substance, and several of them to have small black spots in the midst of those yellow ones, which, to the naked eye, appear'd no bigger then the point of a Pin, or the smallest black spot or tittle of Ink one is able to make with a very sharp pointed Pen.

Examining these with a *Microscope*, I was able plainly to distinguish,up and down the surface, several small yellow knobs, of a kind of yellowish red gummy substance, out of which I perceiv'd there sprung multitudes of little cases or black bodies like Seed-cods, and those of them that were quite without the hillock of Gumm, disclos'd themselves to grow out of it with a small Straw-colour'd and transparent stem, the which seed and stem appear'd very like those of common Moss (which I elsewhere describe) but that they were abundantly less, many hundreds of them being not able to equalize one single seed Cod of Moss.

I have often doubted whether they were the seed Cods of some little Plant, or some kind of small Buds, or the Eggs of some very small Insect, they appear'd of a dark brownish red, some almost quite black, and of a Figure much resembling the seed-cod of Moss, but their stalks on which they grew were of a very fine transparent substance, almost like the stalk of mould, but that they seem'd somewhat more yellow.

That which makes me to suppose them to be Vegetables, is for that I perceiv'd many of those hillocks bare or destitute, as if those bodies lay yet conceal'd,as G. In others of them,they were just springing out of their gummy hillocks, which all seem'd to shoot directly outwards, as at A. In others, as at B, I found them just gotten out,with very little or no stalk,

and the Cods of an indifferent cize;but in others,as C, I found them begin to have little ſhort ſtalks, or ſtems; in others, as D, thoſe ſtems were grown bigger, and larger; and in others, as at E, F, H, I, K, L, *&c.* thoſe ſtems and Cods were grown a great deal bigger, and the ſtalks were more bulky about the root, and very much taper'd towards the top, as at F and L is moſt viſible.

I did not find that any of them had any ſeed in them, or that any of them were hollow, but as they grew bigger and bigger, I found thoſe heads or Cods begin to turn their tops towards their roots, in the ſame manner as I had obſerv'd that of Moſs to do; ſo that in all likelihood, Nature did intend in that poſture, what ſhe does in the like ſeed-cods of greater bulk, that is, that the ſeed, when ripe, ſhould be ſhaken out and diſperſed at the end of it, as we find in Columbine Cods, and the like.

The whole Oval OOOO in the ſecond *Figure* of the 12. *Scheme* repreſents a ſmall part of a Roſe leaf, about the bigneſs of the little Oval in the hillock, C, marked with the Figure X. in which I have not particularly obſerv'd all the other forms of the ſurface of the Roſe-leaf, as being little to my preſent purpoſe.

Now, if theſe Cods have a ſeed in them ſo proportion'd to the Cod, as thoſe of *Pinks*, and *Carnations*, and *Columbines*, and the like, how unimaginably ſmall muſt each of thoſe ſeeds neceſſarily be, for the whole length of one of the largeſt of thoſe Cods was not $\frac{1}{500}$ part of an Inch; ſome not above $\frac{1}{1000}$, and therefore certainly, very many thouſand of them would be unable to make a bulk that ſhould be viſible to the naked eye; and if each of theſe contain the Rudiments of a young Plant of the ſame kind, what muſt we ſay of the pores and conſtituent parts of that?

The generation of this Plant ſeems in part,aſcribable to a kind of *Mildew* or *Blight*,whereby the parts of the leaves grow ſcabby, or putrify'd, as it were, ſo as that the moiſture breaks out in little ſcabs or ſpots, which, as I ſaid before, look like little knobs of a red gummous ſubſtance.

From this putrify'd ſcabb breaks out this little Vegetable; which may be ſomewhat like a *Mould* or *Moſs*; and may have its *equivocal* generation much after the ſame manner as I have ſuppoſed *Moſs* or *Mould* to have, and to be a more ſimple and uncompounded kind of vegetation, which is ſet a moving by the *putrifactive* and *fermentative* heat, joyn'd with that of the ambient aerial, when (by the putrifaction and decay of ſome other parts of the vegetable, that for a while ſtaid its progreſs) it is unfetter'd and left at liberty to move in its former courſe, but by reaſon of its *regulators*, moves and acts after quite another manner then it did when a *coagent* in the more compounded *machine* of the more perfect Vegetable.

And from this very ſame Principle, I imagine the *Miſleto* of Oaks, Thorns, Appletrees, and other Trees, to have its original: It ſeldom or never growing on any of thoſe Trees,till they begin to wax decrepid,and decay with age, and are peſter'd with many other infirmities.

Hither alſo may be referr'd thoſe multitudes and varieties of *Muſhroms*, ſuch as that,call'd *Jews-ears*, all ſorts of *gray* and *green* Moſſes, &c. which infeſt

infeſt all kind of Trees, ſhrubs, and the like, eſpecially when they come to any bigneſs. And this we ſee to be very much the method of Nature throughout its operations, *putrifactive Vegetables* very often producing a Vegetable of a much leſs compounded nature, and of a much inferiour tribe; and *putrefactive* animal ſubſtances degenerating into ſome kind of animal production of a much inferiour rank, and of a more ſimple nature.

Thus we find the humours and ſubſtances of the body, upon *putrifaction*, to produce ſtrange kinds of moving Vermine: the *putrifaction* of the ſlimes and juices of the Stomack and Guts, produce Worms almoſt like Earth-worms, the Wheals in childrens hands produce a little Worm, call'd a *Wheal-worm*: The bloud and milk, and other humours, produce other kinds of Worms, at leaſt, if we may believe what is deliver'd to us by very famous Authors; though, I confeſs, I have not yet been able to diſcover ſuch my ſelf.

And whereas it may ſeem ſtrange that *Vinegar*, *Meal*, muſty *Casks*, &c. are obſerv'd to breed their differing kinds of Inſects, or living creatures, whereas they being Vegetable ſubſtances, ſeem to be of an inferiour kind, and ſo unable to produce a creature more noble, or of a more compounded nature then they themſelves are of, and ſo without ſome concurrent ſeminal principle, may be thought utterly unfit for ſuch an operation; I muſt add, that we cannot preſently poſitively ſay, there are no animal ſubſtances, either mediately, as by the ſoil or fatning of the Plant from whence they ſprung, or more immediately, by the real mixture or compoſition of ſuch ſubſtances, join'd with them; or perchance ſome kind of Inſect, in ſuch places where ſuch kind of *putrifying* or *fermenting* bodies are, may, by a certain inſtinct of nature, eject ſome ſort of ſeminal principle, which cooperating with various kinds of *putrifying* ſubſtances, may produce various kinds of Inſects, or Animate bodies: For we find in moſt ſorts of thoſe lower degrees of Animate bodies, that the *putrifying* ſubſtances on which theſe Eggs, Seeds, or ſeminal principles are caſt by the Inſect, become, as it were, the *Matrices* or Wombs that conduce very much to their generation, and may perchance alſo to their variation and alteration, much after the ſame manner, as, by ſtrange and unnatural copulations, ſeveral new kinds of Animals are produc'd, as *Mules*, and the like, which are uſually call'd Monſtrous, becauſe a little unuſual, though many of them have all their principal parts as perfectly ſhap'd and adapted for their peculiar uſes, as any of the moſt perfect Animals. If therefore the *putrifying* body, on which any kind of ſeminal or vital principle chances to be caſt, become ſomewhat more then meerly a nurſing and foſtering helper in the generation and production of any kind of Animate body, the more neer it approaches the true nature of a Womb, the more power will it have on the by-blow it incloſes. But of this ſomewhat more in the deſcription of the *Water-gnat*. Perhaps ſome more accurate Enquiries and Obſervations about theſe matters might bring the Queſtion to ſome certainty, which would be of no ſmall concern in Natural Philoſophy.

But that *putrifying* animal ſubſtances may produce animals of an inferior

 kind,

kind, I see not any so very great a difficulty, but that one may, without much absurdity, admit: For as there may be multitudes of contrivances that go to the making up of one compleat Animate body; so, That some of those *coadjutors*, in the perfect existence and life of it, may be vitiated, and the life of the whole destroyed, and yet several of the constituting contrivances remain intire, I cannot think it beyond imagination or possibility; no more then that a like accidental process, as I have elswhere hinted, may also be supposed to explicate the method of Nature in the *Metamorphosis* of Plants. And though the difference between a Plant and an Animal be very great, yet I have not hitherto met with any so *cogent* an Argument, as to make me positive in affirming these two to be altogether *Heterogeneous*, and of quite differing kinds of Nature: And besides, as there are many *Zoophyts*, and sensitive Plants (divers of which I have seen, which are of a middle nature, and seem to be Natures transition from one degree to another, which may be observ'd in all her other passages, wherein she is very seldom observ'd to leap from one step to another) so have we, in some Authors, Instances of Plants turning into Animals, and Animals into Plants, and the like; and some other very strange (because unheeded) proceedings of Nature; something of which kind may be met with, in the description of the *Water-Gnat*, though it be not altogether so direct to the present purpose.

But to refer this Discourse of Animals to their proper places, I shall add, that though one should suppose, or it should be prov'd by Observations, that several of these kinds of Plants are accidentally produc'd by a casual *putrifaction*, I see not any great reason to question, but that, notwithstanding its own production was as 'twere casual, yet it may germinate and produce seed, and by it propagate its own, that is, a new Species. For we do not know, but that the Omnipotent and All-wise Creator might as directly design the structure of such a Vegetable, or such an Animal to be produc'd out of such or such a *putrifaction* or change of this or that body, towards the constitution or structure of which, he knew it necessary, or thought it fit to make it an ingredient; as that the digestion or moderate heating of an Egg, either by the Female, or the Sun, or the heat of the Fire, or the like, should produce this or that Bird; or that *Putrifactive* and warm steams should, out of the blowings, as they call them, that is, the Eggs of a Flie, produce a living Magot, and that, by degrees, be turn'd into an *Aurelia*, and that, by a longer and a proportion'd heat, be *transmuted* into a Fly. Nor need we therefore to suppose it the more imperfect in its kind, then the more compounded Vegetable or Animal of which it is a part; for he might as compleatly furnish it with all kinds of contrivances necessary for its own existence, and the propagation of its own Species, and yet make it a part of a more compounded body: as a Clock-maker might make a Set of Chimes to be a part of a Clock, and yet, when the watch part or striking part are taken away, and the hindrances of its motion remov'd, this chiming part may go as accurately, and strike its tune as exactly, as if it were still a part of the compounded *Automaton*. So, though the original cause, or seminal




Schem : XI.
Fig. 1
A
B
C
D
E
Fig. 2
X
G
H
I
K

feminal principle from which this minute Plant on Rofe leaves did fpring, were, before the corruption caus'd by the Mill-dew, a component part of the leaf on which it grew, and did ferve as a *coagent* in the production and conftitution of it, yet might it be fo confummate, as to produce a feed which might have a power of propagating the fame fpecies: the works of the Creator feeming of fuch an excellency, that though they are unable to help to the perfecting of the more compounded exiftence of the greater Plant or Animal, they may have notwithftanding an ability of acting fingly upon their own internal principle, fo as to produce a Vegetable body, though of a lefs compounded nature, and to proceed fo farr in the method of other Vegetables, as to bear flowers and feeds, which may be capabale of propagating the like. So that the little cafes which appear to grow on the top of the flender ftalks, may, for ought I know, though I fhould fuppofe them to fpring from the perverting of the ufual courfe of the parent Vegetable, contain a feed, which, being fcatter'd on other leaves of the fame Plant, may produce a Plant of much the fame kind.

Nor are Damafk-Rofe leaves the onely leaves that produce thefe kinds of Vegetable fproutings; for I have obferv'd them alfo in feveral other kinds of Rofe leaves, and on the leaves of feveral forts of Briers, and on Bramble leaves they are oftentimes to be found in very great clufters; fo that I have found in one clufter, three, four, or five hundred of them, making a very confpicuous black fpot or fcab on the back fide of the leaf.

Obferv. XX. *Of* blue Mould, *and of the firft Principles of Vegetation arifing from* Putrefaction.

THe Blue and White and feveral kinds of hairy mouldy fpots, which are obfervable upon divers kinds of *putrify'd* bodies, whether Animal fubftances, or Vegetable, fuch as the fkin, raw or drefs'd, flefh, bloud, humours, milk, green Cheefe, *&c.* or rotten fappy Wood, or Herbs, Leaves, Barks, Roots, *&c.* of Plants, are all of them nothing elfe but feveral kinds of fmall and varioufly figur'd Mufhroms, which, from convenient materials in thofe *putrifying* bodies, are, by the concurrent heat of the Air, excited to a certain kind of vegetation, which will not be unworthy our more ferious fpeculation and examination, as I fhall by and by fhew. But, firft, I muft premife a fhort defcription of this *Specimen*, which I have added of this Tribe, in the firft Figure of the XII. *Scheme*, which is nothing elfe but the appearance of a fmall white fpot of hairy mould, multitudes of which I found to befpeck & whiten over the red covers of a fmall book, which, it feems, were of Sheeps-fkin, that being more apt to gather mould, even in a dry and clean room, then other leathers. Thefe fpots appear'd, through a good *Microfcope*, to be a very pretty fhap'd Vegetative body, which, from almoft the fame part of the Leather, fhot

out

out multitudes of ſmall long cylindrical and tranſparent ſtalks,not exactly ſtreight,but a little bended with the weight of a round and white knob that grew on the top of each of them; many of theſe knobs I obſerv'd to be very round, and of a ſmooth ſurface, ſuch as A A, *&c.* others ſmooth likewiſe,but a little oblong,as B; ſeveral of them a little broken, or cloven with chops at the top, as C; others flitter'd as 'twere, or flown all to pieces, as D D. The whole ſubſtance of theſe pretty bodies was of a very tender conſtitution, much like the ſubſtance of the ſofter kind of common white Muſhroms, for by touching them with a Pin, I found them to be bruſed and torn; they ſeem'd each of them to have a diſtinct root of their own; for though they grew neer together in a cluſter, yet I could perceive each ſtem to riſe out of a diſtinct part or pore of the Leather; ſome of theſe were ſmall and ſhort, as ſeeming to have been but newly ſprung up, of theſe the balls were for the moſt part round, others were bigger,and taller,as being perhaps of a longer growth,and of theſe, for the moſt part, the heads were broken, and ſome much waſted, as E; what theſe heads contain'd I could not perceive; whether they were knobs and flowers, or ſeed caſes, I am not able to ſay, but they ſeem'd moſt likely to be of the ſame nature with thoſe that grow on Muſhroms, which they did,ſome of them, not a little reſemble.

Both their ſmell and taſte, which are active enough to make a ſenſible impreſſion upon thoſe organs, are unpleaſant and noiſome.

I could not find that they would ſo quickly be deſtroy'd by the actual flame of a Candle, as at firſt ſight of them I conceived they would be,but they remain'd intire after I had paſt that part of the Leather on which they ſtuck three or four times through the flame of a Candle; ſo that, it ſeems they are not very apt to take fire, no more then the common white Muſhroms are when they are ſappy.

There are a multitude of other ſhapes, of which theſe *Microſcopical* Muſhroms are figur'd, which would have been a long Work to have deſcribed,and would not have ſuited ſo well with my deſign in this Treatiſe, onely,amongſt the reſt, I muſt not forget to take notice of one that was a little like to, or reſembled, a Spunge, conſiſting of a multitude of little Ramifications almoſt as that body does, which indeed ſeems to be a kind of Water-Muſhrom, of a very pretty texture, as I elſe-where manifeſt. And a ſecond, which I muſt not omit, becauſe often mingled, and neer adjoining to theſe I have deſcrib'd,and this appear'd much like a Thicket of buſhes, or brambles, very much branch'd,and extended,ſome of them, to a great length,in proportion to their Diameter,like creeping brambles.

The manner of the growth and formation of this kind of Vegetable, is the third head of Enquiry,which, had I time,I ſhould follow: the figure and method of Generation in this concrete ſeeming to me, next after the Enquiry into the formation, figuration, or chryſtalization of Salts, to be the moſt ſimple, plain, and eaſie; and it ſeems to be a *medium* through which he muſt neceſſarily paſs, that would with any likelihood inveſtigate the *forma informans* of Vegetables: for as I think that he ſhall find it a very difficult taſk, who undertakes to diſcover the form of Saline

line cryſtallizations, without the conſideration and preſcience of the nature and reaſon of a Globular form, and as difficult to explicate this configuration of Muſhroms, without the previous conſideration of the form of Salts; ſo will the enquiry into the forms of Vegetables be no leſs, if not much more difficult, without the fore-knowledge of the forms of Muſhroms, theſe ſeveral Enquiries having no leſs dependance one upon another then any ſelect number of Propoſitions in Mathematical Elements may be made to have.

Nor do I imagine that the ſkips from the one to another will be found very great, if beginning from fluidity, or body without any form, we deſcend gradually, till we arrive at the higheſt form of a bruite Animal's Soul, making the ſteps or foundations of our Enquiry, *Fluidity, Orbiculation, Fixation, Angulization*, or *Cryſtallization Germination* or *Ebullition, Vegetation, Plantanimation, Animation, Senſation, Imagination.*

Now, that we may the better proceed in our Enquiry, It will be requiſite to conſider:

Firſt, that Mould and Muſhroms require no ſeminal property, but the former may be produc'd at any time from any kind of *putrifying* Animal, or Vegetable Subſtance, as Fleſh, *&c.* kept moiſt and warm, and the latter, if what *Mathiolus* relates be true, of making them by Art, are as much within our command, of which Matter take the *Epitomie* which Mr. *Parkinſon* has deliver'd in his *Herbal*, in his Chapter of *Muſhroms*, becauſe I have not *Mathiolus* now by me: *Unto theſe Muſhroms* (ſaith he) *may alſo be adjoyn'd thoſe which are made of Art* (*whereof* Mathiolus *makes mention*) *that grow naturally among certain ſtones in* Naples, *and that the ſtones being digg'd up, and carried to* Rome, *and other places, where they ſet them in their Wine Cellars, covering them with a little Earth, and ſprinkling a little warm water thereon, would within four days produce Muſhroms fit to be eaten, at what time one will: As alſo that Muſhroms may be made to grow at the foot of a wilde* Poplar Tree, *within four days after, warm water wherein ſome leaves have been diſſolv'd ſhall be pour'd into the Root* (*which muſt be ſlit*) *and the ſtock above ground.*

Next, that as Muſhroms may be generated without ſeed, ſo does it not appear that they have any ſuch thing as ſeed in any part of them; for having conſidered ſeveral kinds of them, I could never find any thing in them that I could with any probability gheſs to be the ſeed of it, ſo that it does not as yet appear (that I know of) that Muſhroms may be generated from a ſeed, but they rather ſeem to depend merely upon a convenient conſtitution of the matter out of which they are made, and a concurrence of either natural or artificial heat.

Thirdly, that by ſeveral bodies (as Salts and Metals both in Water and in the air, and by ſeveral kinds of ſublimations in the Air) actuated and guided with a congruous heat, there may be produc'd ſeveral kinds of bodies as curiouſly, if not of a more compos'd Figure; ſeveral kinds of riſing or Ebulliating Figures ſeem to manifeſt; as witneſs the ſhooting in the Rectification of ſpirits of *Urine, Hart-horn, Bloud*, &c. witneſs alſo the curious branches of evaporated diſſolutions, ſome of them againſt

the sides of the containing Jar: others standing up, or growing an end, out of the bottom, of which I have taken notice of a very great variety. But above all the rest, it is a very pretty kind of Germination which is afforded us in the Silver Tree, the manner of making which with Mercury and Silver, is well known to the Chymists, in which there is an Ebullition or Germination, very much like this of Mushroms, if I have been rightly inform'd of it.

Fourthly, I have very often taken notice of, and also observ'd with a *Microscope*, certain excrescencies or Ebullitions in the snuff of a Candle, which, partly from the sticking of the smoaky particles, as they are carryed upwards by the current of the rarify'd Air and flame, and partly also from a kind of Germination or Ebullition of some actuated unctuous parts which creep along and filter through some small string of the Week, are formed into pretty round and uniform heads, very much resembling the form of hooded Mushroms, which, being by any means expos'd to the fresh Air, or that air which encompasses the flame, they are presently lick'd up and devour'd by it, and vanish.

The reason of which *Phænomenon* seems to me, to be no other then this:

That when a convenient thread of the Week is so bent out by the sides of the snuff that are about half an Inch or more, remov'd above the bottom, or lowest part of the flame, and that this part be wholly included in the flame; the Oyl (for the reason of filtration, which I have elsewhere rendred) being continualy driven up the snuff, is driven likewise into this ragged, bended-end, and this being remov'd a good distance, as half an Inch or more, above the bottom of the flame, the parts of the air that passes by it, are already, almost satiated with the dissolution of the boiling unctuous steams that issued out below, and therefore are not onely glutted, that is, can dissolve no more then what they are already acting upon, but they carry up with them abundance of unctuous and sooty particles, which meeting with that rag of the Week, that is plentifully fill'd with Oyl, and onely spends it as fast as it evaporates, and not at all by dissolution or burning, by means of these steamy parts of the filterated Oyl issuing out at the sides of this ragg, and being inclos'd with an air that is already satiated and cannot prey upon them nor burn them, the ascending sooty particles are stay'd about it and fix'd, so as that about the end of that ragg or filament of the snuff, whence the greatest part of the steams issue, there is conglobated or fix'd a round and pretty uniform cap, much resembling the head of a Mushrom, which, if it be of any great bigness, you may observe that its underside will be bigger then that which is above the ragg or stem of it; for the Oyl that is brought into it by filtration, being by the bulk of the cap a little shelter'd from the heat of the flame, does by that means issue as much out from beneath from the stalk or downwards, as it does upwards, and by reason of the great access of the adventitious smoak from beneath, it increases most that way. That this may be the true reason of this *Phænomenon*, I could produce many Arguments and Experiments to make it probable: As,

First, that the *Filtration* carries the Oyl to the top of the Week, at least

as

as high as these raggs, is visible to one that will observe the snuff of a burning Candle with a *Microscope*, where he may see an Ebullition or bubbling of the Oyl, as high as the snuff looks black.

Next, that it does steam away more then burn; I could tell you of the dim burning of a Candle, the longer the snuff be which arises from the abundance of vapours out of the higher parts of it.

And, thirdly, that in the middle of the flame of the Candle, neer the top of the snuff, the fire or dissolving principle is nothing neer so strong, as neer the bottom and out edges of the flame, which may be observ'd by the burning asunder of a thread, that will first break in those parts that the edges of the flame touch, and not in the middle.

And I could add several Observables that I have taken notice of in the flame of a Lamp actuated with Bellows, and very many others that confirm me in my opinion, but that it is not so much to my present purpose, which is onely to consider this concreet in the snuff of a Candle, so farr as it has any resemblance of a Mushrom, to the consideration of which, that I may return, I say, we may also observe:

In the first place, that the droppings or trillings of Lapidescent waters in Vaults under ground, seem to constitute a kind of *petrify'd* body, form'd almost like some kind of Mushroms inverted, in so much that I have seen some knobb'd a little at the lower end, though for the most part, indeed they are otherwise shap'd, and taper'd towards the end; the generation of which seems to be from no other reason but this, that the water by soaking through the earth and Lime (for I ghess that substance to add much to it *petrifying* quality) does so impregnate it self with stony particles, that hanging in drops in the roof of the Vault, by reason that the soaking of the water is but slow, it becomes expos'd to the Air, and thereby the outward part of the drop by degrees grows hard, by reason that the water gradually evaporating the stony particles neer the outsides of the drop begin to touch, and by degrees, to dry and grow closer together, and at length constitute a crust or shell about the drop; and this soaking by degrees, being more and more supply'd, the drop grows longer and longer, and the sides harden thicker and thicker into a Quill or Cane, and at length, that hollow or pith becomes almost stop'd up, and solid: afterwards the soaking of the *petrifying* water, finding no longer a passage through the middle, bursts out, and trickles down the outside, and as the water evaporates, leaves new superinduc'd shells; which more and more swell the bulk of those Iceicles; and because of the great supply from the Vault, of *petrifying* water, those bodies grow bigger and bigger next to the Vault, and taper or sharpen towards the point; for the access from the arch of the Vault being but very slow, and consequently the water being spread very thinly over the surface of the Iceicle, the water begins to settle before it can reach to the bottom, or corner end of it; whence, if you break one of these, you would almost imagine it a stick of Wood *petrify'd*, it having so pretty a resemblance of pith and grain, and if you look on the outside of a piece, or of one whole, you would think no less, both from its vegetable roundness and

tapering form; but whereas all Vegetables are obſerv'd to ſhoot and grow perpendicularly upwards, this does ſhoot or propend directly downwards.

By which laſt Obſervables, we ſee that there may be a very pretty body ſhap'd and concreeted by Mechanical principles, without the leaſt ſhew or probability of any other ſeminal *formatrix*.

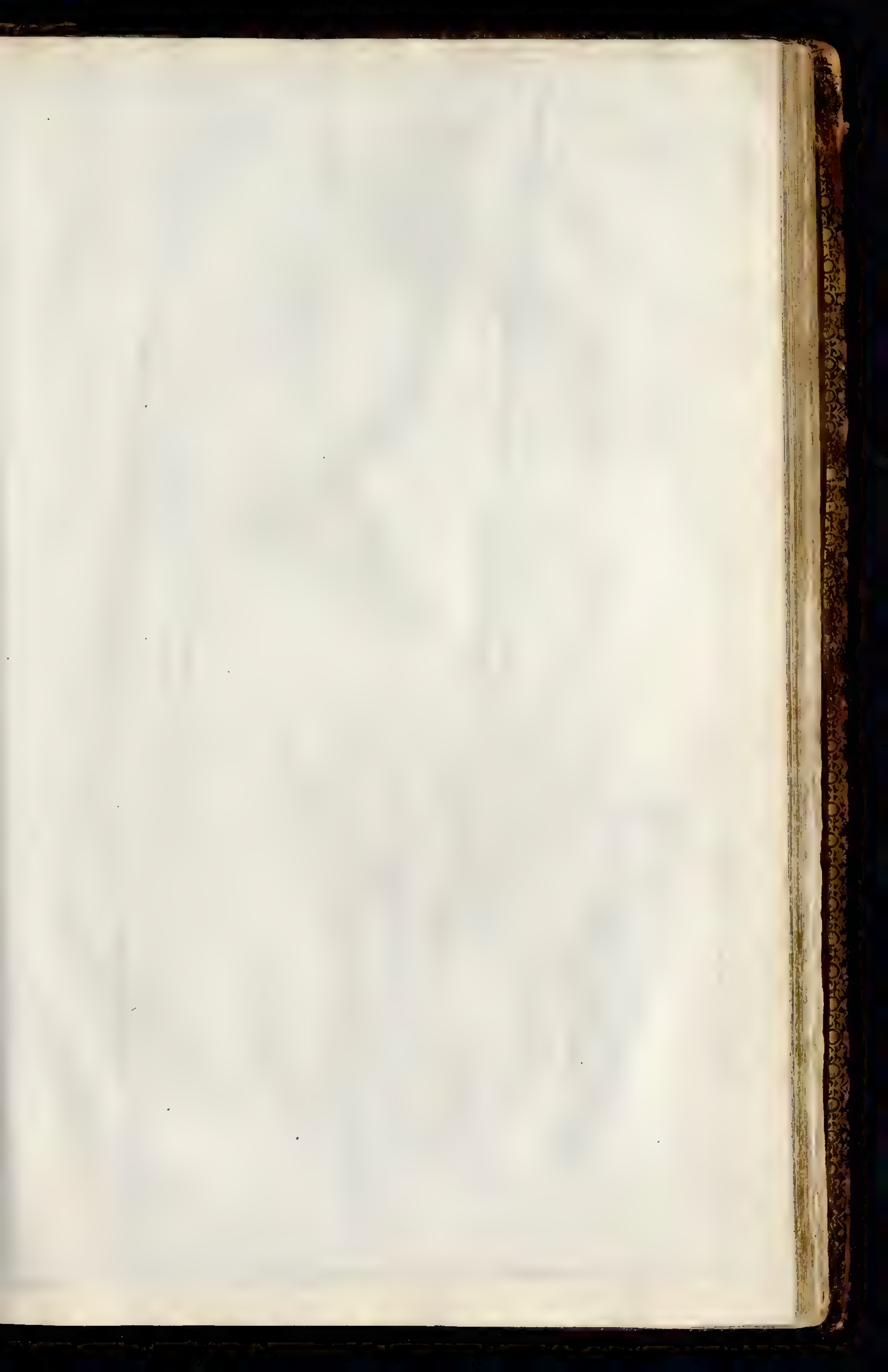
And ſince we find that the great reaſon of the *Phænomena* of this pretty *petrifaction*, are to be reduc'd from the gravity of a fluid and pretty volatil body impregnated with ſtony particles, why may not the *Phænomena* of Ebullition or Germination be in part poſſibly enough deduc'd from the levity of an impregnated liquor, which therefore perpendicularly aſcending by degrees, evaporates and leaves the more ſolid and fix'd parts behind in the form of a Muſhrom, which is yet further diverſify'd and ſpecificated by the forms of the parts that impregnated the liquor, and compoſe or help to conſtitute the Muſhrom.

That the foremention'd Figures of growing Salts, and the Silver Tree, are from this principle, I could very eaſily manifeſt; but that I have not now a convenient opportunity of following it, nor have I made a ſufficient number of Experiments and Obſervations to propound, explicate, and prove ſo uſefull a *Theory* as this of Muſhroms: for, though the contrary principle to that of *petrify'd* Iceicles may be in part a cauſe; yet I cannot but think, that there is ſomewhat a more complicated cauſe, though yet Mechanical, and poſſible to be explain'd.

We therefore have further to enquire of it, what makes it to be ſuch a liquor, and to aſcend, whether the heat of the Sun and Air, or whether that of *firmentiation* and *putrifaction*, or both together; as alſo whether there be not a third or fourth; whether a Saline principle be not a conſiderable agent in this buſineſs alſo as well as heat; whether alſo a fixation, precipitation or ſettling of certain parts out of the aerial Muſhrom may not be alſo a conſiderable coadjutor in the buſineſs. Since we find that many pretty beards or *ſtiriæ* of the particles of Silver may be precipitated upon a piece of Braſs put into a *ſolution* of Silver very much diluted with fair water, which look not unlike a kind of mould or hoar upon that piece of metal; and the hoar froſt looks like a kind of mould; and whether there may not be ſeveral others that do concurr to the production of a Muſhrom, having not yet had ſufficient time to proſecute according to my deſires, I muſt referr this to a better opportunity of my own, or leave and recommend it to the more diligent enquiry and examination of ſuch as can be maſters both of leiſure and conveniencies for ſuch an Enquiry.

And in the mean time, I muſt conclude, that as far as I have been able to look into the nature of this Primary kind of life and vegetation, I cannot find the leaſt probable argument to perſwade me there is any other concurrent cauſe then ſuch as is purely Mechanical, and that the effects or productions are as neceſſary upon the concurrence of thoſe cauſes as that a Ship, when the Sails are hoiſt up, and the Rudder is ſet to ſuch a poſition, ſhould, when the Wind blows, be mov'd in ſuch a way or courſe

to




B
A
C
F

to that or t'other place; Or, as that the brufed Watch, which I mention in the defcription of Mofs, fhould, when thofe parts which hindred its motion were fallen away, begin to move, but after quite another manner then it did before.

Obferv. XXI. *Of* Mofs, *and feveral other fmall vegetative Subftances.*

MOfs is a Plant, that the wifeft of Kings thought neither unworthy his fpeculation, nor his Pen, and though amongft Plants it be in bulk one of the fmalleft, yet it is not the leaft confiderable: For, as to its fhape, it may compare for the beauty of it with any Plant that grows, and bears a much bigger breadth; it has a root almoft like a feedy Parfnep, furnifh'd with fmall ftrings and fuckers, which are all of them finely branch'd, like thofe of the roots of much bigger Vegetables; out of this fprings the ftem or body of the Plant, which is fomewhat *Quadrangular*, rather then *Cylindrical*, moft curioufly *fluted* or ftrung with fmall creafes, which run, for the moft part, *parallel* the whole ftem; on the fides of this are clofe and thick fet, a multitude of fair, large, well-fhap'd leaves, fome of them of a rounder, others of a longer fhape, according as they are younger or older when pluck'd; as I ghefs by this, that thofe Plants that had the ftalks growing from the top of them, had their leaves of a much longer fhape, all the furface of each fide of which, is curioufly cover'd with a multitude of little oblong tranfparent bodies, in the manner as you fee it exprefs'd in the leaf B, in the XIII. *Scheme.*

This Plant, when young and fpringing up, does much refemble a Houfleek, having thick leaves, almoft like that, and feems to be fomwhat of kin to it in other particulars; alfo from the top of the leaves, there fhoots out a fmall white and tranfparent hair, or thorn: This ftem, in time, come to fhoot out into a long, roundand even ftalk, which by cutting tranfverfly, when dry, I manifeftly found to be a ftiff, hard, and hollow Cane, or Reed, without any kind of knot, or ftop, from its bottom, where the leaves encompafs'd it, to the top, on which there grows a large feed cafe, A, cover'd with a thin, and more whitifh fkin, B, terminated in a long thorny top, which at firft covers all the Cafe, and by degrees, as that fwells, the fkin cleaves, and at length falls off, with its thorny top and all (which is a part of it) and leaves the feed Cafe to ripen, and by degrees, to fhatter out its feed at a place underneath this cap, B, which before the feed is ripe, appears like a flat barr'd button, without any hole in the middle; but as it ripens, the button grows bigger, and a hole appears in the middle of it, E, out of which, in all probability, the feed falls: For as it ripens by a provifion of Nature, that end of this Cafe turns downward after the fame manner as the ears of Wheat and Barley ufually do; and opening feveral of thefe dry red Cafes, F, I found them to be

may be caus'd by a vegetative principle, which was a coadjutor to the life and growth of the greater Vegetable, and was by the deſtroying of the life of it ſtopt and impeded in performing its office; but afterwards, upon a further corruption of ſeveral parts that had all the while impeded it, the heat of the Sun winding up, as it were, the ſpring, ſets it again into a vegetative motion, and this being ſingle, and not at all regulated as it was before(when a part of that greater *machine* the priſtine vegetable)is mov'd after quite a differing manner,and produces effects very differing from thoſe it did before.

But this I propound onely as a conjecture, not that I am more enclin'd to this *Hypotheſis* then the ſeminal, which upon good reaſon I gheſs to be Mechanical alſo, as I may elſewhere more fully ſhew: But becauſe I may, by this,hint a poſſible way how this appearance may be ſolv'd; ſuppoſing we ſhould be driven to confeſs from certain Experiments and Obſervations made, that ſuch or ſuch Vegetables were produc'd out of the corruption of another, without any concurrent ſeminal principle (as I have given ſome reaſon to ſuppoſe, in the deſcription of a *Microſcopical* Muſhrome) without derogating at all from the infinite wiſdom of the Creator. For this accidental production, as I may call it, does manifeſt as much, if not very much more, of the excellency of his contrivance as any thing in the more perfect vegetative bodies of the world, even as the accidental motion of the *Automaton* does make the owner ſee, that there was much more contrivance in it then at firſt he imagin'd. But of this I have added more in the deſcription of Mould,and the Vegetables on Roſe leaves,&c. thoſe being much more likely to have their original from ſuch a cauſe then this which I have here deſcribed, in the 13. *Scheme*, which indeed I cannot conceive otherwiſe of, then as of a moſt perfect Vegetable, wanting nothing of the perfections of the moſt conſpicuous and vaſteſt Vegetables of the world, and to be of a rank ſo high, as that it may very properly be reckon'd with the tall Cedar of *Lebanon*, as that Kingly Botaniſt has done.

We know there may be as much curioſity of contrivance, and excellency of form in a very ſmall Pocket-clock, that takes not up an Inch ſquare of room,as there may be in a Church-clock that fills a whole room; And I know not whether all the contrivances and *Mechaniſms* requiſite to a perfect Vegetable, may not be crowded into an exceedingly leſs room then this of Moſs, as I have heard of a ſtriking Watch ſo ſmall, that it ſerv'd for a Pendant in a Ladies ear; and I have already given you the deſcription of a Plant growing on Roſe leaves, that is abundantly ſmaller then Moſs; inſomuch, that neer 1000. of them would hardly make the bigneſs of one ſingle Plant of Moſs. And by comparing the bulk of Moſs, with the bulk of the biggeſt kind of Vegetable we meet with in Story (of which kind we find in ſome hotter climates, as *Guine*, and *Braſile*, the ſtock or body of ſome Trees to be twenty foot in Diameter, whereas the body or ſtem of Moſs, for the moſt part, is not above one ſixtieth part of an Inch) we ſhall find that the bulk of the one will exceed the bulk of the other, no leſs then 2985984 Millions,

or

or 2985984000000, and ſuppoſing the production on a Roſe leaf to be a Plant, we ſhall have of thoſe *Indian* Plants to exceed a production of the ſame Vegetable kingdom no leſs then 1000 times the former number; ſo prodigiouſly various are the works of the Creator, and ſo All-ſufficient is he to perform what to man would ſeem unpoſſible, they being both alike eaſie to him, even as one day, and a thouſand years are to him as one and the ſame time.

I have taken notice of ſuch an infinite variety of thoſe ſmaller kinds of vegetations, that ſhould I have deſcribed every one of them, they would almoſt have fill'd a Volume, and prov'd bigg enough to have made a new Herbal, ſuch multitudes are there to be found in moiſt hot weather, eſpecially in the Summer time, on all kind of putrifying ſubſtances, which, whether they do more properly belong to the *Claſſis* of *Muſhroms*, or *Moulds*, or *Moſſes*, I ſhall not now diſpute, there being ſome that ſeem more properly of one kind, others of another, their colours and magnitudes being as much differing as their Figures and ſubſtances.

Nay, I have obſerv'd, that putting fair Water (whether Rain-water or Pump-water, or *May-dew*, or Snow-water, it was almoſt all one) I have often obſerv'd, I ſay, that this Water would, with a little ſtanding, tarniſh and cover all about the ſides of the Glaſs that lay under water, with a lovely green; but though I have often endeavour'd to diſcover with my *Microſcope* whether this green were like Moſs, or long ſtriped Sea-weed, or any other peculiar form, yet ſo ill and imperfect are our *Microſcopes*, that I could not certainly diſcriminate any.

Growing Trees alſo, and any kinds of Woods, Stones, Bones, &c. that have been long expos'd to the Air and Rain, will be all over cover'd with a greeniſh ſcurff, which will very much foul and green any kind of cloaths that are rubb'd againſt it; viewing this, I could not certainly perceive in many parts of it any determinate form, though in many I could perceive a Bed as 'twere of young Moſs, but in other parts it look'd almoſt like green buſhes, and very confus'd, but always of what ever irregular Figures the parts appear'd of, they were always green, and ſeem'd to be either ſome Vegetable, or to have ſome vegetating principle.

Obſerv. XXII. *Of common* Sponges, *and ſeveral other* Spongie *fibrous bodies.*

A Sponge is commonly reckon'd among the *Zoophyts*, or Plant Animals; and the *texture* of it, which the *Microſcope* diſcovers, ſeems to confirm it; for it is of a form whereof I never obſerv'd any other Vegetable, and indeed, it ſeems impoſſible that any ſhould be of it, for it conſiſts of an infinite number of ſmall ſhort *fibres*, or nervous parts, much of the ſame bigneſs, curiouſly jointed or contex'd together in the form of a Net, as is more plainly manifeſt by the little Draught which I have added

added, in the third *Figure* of the IX. *Scheme*, of a piece of it, which you may perceive repreſents a confus'd heap of the fibrous parts curiouſly jointed and implicated. The joints are, for the moſt part, where three *fibres* onely meet, for I have very ſeldom met with any that had four.

At theſe joints there is no one of the three that ſeems to be the ſtock whereon the other grow, but each of the *fibres* are, for the moſt part, of an equal bigneſs, and ſeem each of them to have an equal ſhare in the joint; the *fibres* are all of them much about the ſame bigneſs, not ſmaller towards the top of the Sponge, and bigger neerer the bottom or root, as is uſuall in Plants, the length of each between the joints, is very irregular and different; the diſtance between ſome two joints, being ten or twelve times more then between ſome others.

Nor are the joints regular, and of an *equitriagonal Figure*, but, for the moſt part, the three *fibres* ſo meet, that they compoſe three angles very differing all of them from one another.

The meſhes likewiſe, and holes of this reticulated body, are not leſs various and irregular: ſome *bilateral*, others *trilateral*, and *quadrilateral* Figures; nay, I have obſerv'd ſome meſhes to have 5, 6, 7, 8, or 9. ſides, and ſome to have onely one, ſo exceeding various is the *Luſus Naturæ* in this body.

As to the outward appearance of this Vegetative body, they are ſo uſuall every where, that I need not deſcribe them, conſiſting of a ſoft and porous ſubſtance, repreſenting a Lock, ſometimes a fleece of Wooll; but it has beſides theſe ſmall *microſcopical* pores which lie between the *fibres*, a multitude of round pores or holes, which, from the top of it, pierce into the body, and ſometimes go quite through to the bottom.

I have obſerv'd many of theſe Sponges, to have included likewiſe in the midſt of their fibrous contextures, pretty large friable ſtones, which muſt either have been inclos'd whil'ſt this Vegetable was in formation, or generated in thoſe places after it was perfectly ſhap'd. The later of which ſeems the more improbable, becauſe I did not find that any of theſe ſtony ſubſtances were perforated with the *fibres* of the Sponge.

I have never ſeen nor been enform'd of the true manner of the growing of Sponges on the Rock; whether they are found to increaſe from little to great, like Vegetables, that is, part after part, or like Animals, all parts equally growing together; or whether they be *matrices* or ſeed-baggs of any kind of Fiſhes, or ſome kind of watry Inſect; or whether they are at any times more ſoft and tender, or of another nature and texture, which things, if I knew, I ſhould much deſire to be informed of: but from a curſory view that I at firſt made with my *Microſcope*, and ſome other trials, I ſuppoſed it to be ſome Animal ſubſtance caſt out, and faſtned upon the Rocks in the form of a froth, or *congeries* of bubbles, like that which I have often obſerv'd on Roſemary, and other Plants (wherein is included a little Inſect) that all the little films which divide theſe bubbles one from another, did preſently, almoſt after the ſubſtance began to grow a little harder, break, and leave onely the thread behind, which might be, as 'twere, the angle or thread between the bubbles, that the great

great holes or pores obſervable in theſe Sponges were made by the eruption of the included *Heterogeneous* ſubſtance (whether air, or ſome other body, for many other fluid bodies will do the ſame thing) which breaking out of the leſſer, were collected into very large bubbles, and ſo might make their way out of the Sponge, and in their paſſage might leave a round cavity; and if it were large,might carry up with it the adjacent bubbles, which may be perceiv'd at the outſide of the Sponge, if it be firſt throughly wetted, and ſuffer'd to plump it ſelf into its natural form, or be then wrung dry, and ſuffer'd to expand it ſelf again, which it will freely do whil'ſt moiſt: for when it has thus plump'd it ſelf into its natural ſhape and dimenſions, 'tis obvious enough that the mouths of the larger holes have a kind of lip or riſing round about them, but the other ſmaller pores have little or none. It may further be found, that each of theſe great pores has many other ſmall pores below, that are united unto it, and help to conſtitute it, almoſt like ſo many rivulets or ſmall ſtreams that contribute to the maintenance of a large River. Nor from this *Hypotheſis* would it have been difficult to explicate, how thoſe little branches of *Coral*, ſmal *Stones*, *Shells*, and the like, come to be included by theſe frothy bodies: But this inded was but a conjecture; and upon a more accurate enquiry into the form of it with the *Microſcope*, it ſeems not to be the true origine of them; for whereas Sponges have onely three arms which join together at each knot, if they had been generated from bubbles they muſt have had four.

But that they are Animal Subſtances, the *Chymical* examination of them ſeems to manifeſt, they affording a volatil Salt and ſpirit,like *Harts-Horn*, as does alſo their great ſtrength and toughneſs, and their ſmell when burn'd in the Fire or a Candle, which has a kind of fleſhy ſent,not much unlike to hair. And having ſince examin'd ſeveral Authors concerning them,among others,I find this account given by *Bellonius*, in the XI. *Chap.* of his 2[d] Book, *De Aquatilibus. Spongiæ recentes*, ſays he, *à ſiccis longe diverſæ,ſcopulis aquæ marinæ ad duos vel tres cubitos,nonnunquam quatuor tantum digitos immerſis, ut fungi arboribus adhærent, ſordido quodam ſucco aut mucoſa potius ſanie refærtæ,uſque adeò fætida,ut vel eminus nauſeam excitet, continetur autem iis cavernis, quas inanes in ſiccis & lotis Spongiis cernimus: Putris pulmonis modo nigræ conſpiciuntur, verùm quæ in ſublimi aquæ naſcuntur multo magis opaca nigredine ſuffuſæ ſunt. Vivere quidem Spongias adhærendo* Ariſtoteles *cenſet: abſolute vero minime: ſenſumque aliquem habere, vel eo argumento (inquit) credantur, quod difficillime abſtrahantur,niſi clanculum agatur: Atq; ad avulſoris acceſſum ita contrahantur, ut eas evellere difficile ſit, quod idem etiam faciunt quoties flatus tempeſtatéſque urgent. Puto autem illis ſuccum ſordidum quem ſupra [dixímus carnis loco à natura attributum fuiſſe: atque meatibus latioribus tanquam inteſtinis aut interaneis uti. Cæterum pars ea quæ Spongiæ cautibus adhærent eſt tanquam folii petiolus, à quo veluti collum quoddam gracile incipit: quod deinde in latitudinem diffuſum capitis globum facit. Recentibus nihil eſt fiſtuloſum, hæſitantque tanquam radicibus. Superne omnes propemodum meatus concreti latent: inferne verò quaterni aut quini patent, per quos*

eas ſugere exiſtimamus. From which Deſcription, they ſeem to be a kind of Plant-Animal that adheres to a Rock, and theſe ſmall *fibres* or threads which we have deſcribed, ſeem to have been the Veſſels which ('tis very probable) were very much bigger whil'ſt the *Interſtitia* were fill'd (as he affirms) with a mucous,pulpy or fleſhy ſubſtance; but upon the drying were ſhrunk into the bigneſs they now appear.

The texture of it is ſuch, that I have not yet met with any other body in the world that has the like, but onely one of a larger ſort of Sponge (which is preſerv'd in the *Muſeum Harveanum* belonging to the moſt Illuſtrious and moſt learned Society of the *Phyſicians* of *London*) which is of a horney, or rather of a *petrify'd* ſubſtance. And of this indeed, the texture and make is exactly the ſame with common Sponges, but onely that both the holes and the *fibres*, or texture of it is exceedingly much bigger,for ſome of the holes were above an Inch and half over, and the *fibres* and *texture* of it was bigg enough to be diſtinguiſhed eaſily with ones eye, but conſpicuouſly with an ordinary ſingle *Microſcope*. And theſe indeed, ſeem'd to have been the habitation of ſome Animal; and examining *Ariſtotle*, I find a very conſonant account hereunto, namely, that he had known a certain little Animal, call'd *Pinnothera*, like a Spider, to be bred in thoſe caverns of a Sponge,from within which,by opening and cloſing thoſe holes, he inſnares and catches the little Fiſhes; and in another place he ſays, That'tis very confidently reported, that there are certain Moths or Worms that reſide in the cavities of a Sponge,and are there nouriſhed: Notwithſtanding all which Hiſtories,I think it well worth the enquiring into the Hiſtory and nature of a Sponge, it ſeeming to promiſe ſome information of the Veſſels in Animal ſubſtances, which (by reaſon of the ſolidity of the interſerted fleſh that is not eaſily remov'd, without deſtroying alſo thoſe interſpers'd Veſſels) are hitherto undiſcover'd; whereas here in a Sponge,the *Parenchyma*,it ſeems,is but a kind of mucous gelly, which is very eaſily and cleerly waſh'd away.

The reaſon that makes me imagine, that there may probably be ſome ſuch texture in Animal ſubſtances, is, that examining the texture of the filaments of tann'd Leather, I find it to be much of the ſame nature and ſtrength of a Sponge; and with my *Microſcope*, I have obſerv'd many ſuch joints and knobs, as I have deſcribed in Sponges, the *fibres* alſo in the hollow of ſeveral ſorts of Bones, after the Marrow has been remov'd, I have found ſomewhat to reſemble this texture, though, I confeſs, I never yet found any texture exactly the ſame, nor any for curioſity comparable to it.

The filaments of it are much ſmaller then thoſe of Silk, and through the *Microſcope* appear very neer as tranſparent, nay, ſome parts of them I have obſerv'd much more.

Having examin'd alſo ſeveral kinds of Muſhroms, I finde their texture to be ſomewhat of this kind, that is, to conſiſt of an infinite company of ſmall filaments, every way contex'd and woven together, ſo as to make a kind of cloth, and more particularly, examining a piece of Touch-wood (which is a kind of *Jews-ear*, or Muſhrom, growing here in *England* alſo,

on

on ſeveral ſorts of Trees, ſuch as Elders, Maples, Willows, *&c.* and is commonly call'd by the name of *Spunk*; but that we meet with to be ſold in Shops, is brought from beyond Seas) I found it to be made of an exceeding delicate texture: For the ſubſtance of it feels, and looks to the naked eye,and may be ſtretch'd any way,exactly like a very fine piece of *Chamois* Leather, or waſh'd Leather, but it is of ſomewhat a browner hew, and nothing neer ſo ſtrong; but examining it with my *Microſcope*, I found it of ſomewhat another make then any kind of Leather; for whereas both *Chamois*, and all other kinds of Leather I have yet view'd, conſiſt of an infinite company of filaments, ſomewhat like buſhes interwoven one within another, that is,of bigger parts or ſtems, as it were, and ſmaller branchings that grow out of them; or like a heap of Ropes ends, where each of the larger Ropes by degrees ſeem to ſplit or untwiſt, into many ſmaller Cords, and each of thoſe Cords into ſmaller Lines, and thoſe Lines into Threads, *&c.* and theſe ſtrangely intangled, or interwoven one within another: The texture of this Touch-wood ſeems more like that of a Lock or a Fleece of Wool, for it conſiſts of an infinite number of ſmall filaments, all of them, as farr as I could perceive, of the ſame bigneſs like thoſe of a Sponge, but that the *filaments* of this were not a twentieth part of the bigneſs of thoſe of a Sponge; and I could not ſo plainly perceive their joints, or their manner of interweaving, though, as farr as I was able to diſcern with that *Microſcope* I had, I ſuppoſe it to have ſome kind of reſemblance, but the joints are nothing neer ſo thick, nor without much trouble viſible.

The filaments I could plainly enough perceive to be even,round,cylindrical,tranſparent bodies,and to croſs each other every way, that is, there were not more ſeem'd to lie *horizontally* then *perpendicularly* and thwartway, ſo that it is ſomewhat difficult to conceive how they ſhould grow in that manner. By tearing off a ſmall piece of it, and looking on the ragged edge, I could among ſeveral of thoſe *fibres* perceive ſmall joints, that is, one of thoſe hairs ſplit into two, each of the ſame bigneſs with the other out of which they ſeem'd to grow, but having not lately had an opportunity of examining their manner of growth, I cannot poſitively affirm any thing of them.

But to proceed, The ſwelling of Sponges upon wetting, and the riſing of the Water in it above the ſurface of the Water that it touches, are both from the ſame cauſe, of which an account is already given in the ſixth Obſervation.

The ſubſtance of them indeed, has ſo many excellent properties,ſcarce to be met with in any other body in the world, that I have often wondered that ſo little uſe is made of it, and thoſe onely vile and ſordid; certainly, if it were well conſider'd, it would afford much greater conveniencies.

That uſe which the Divers are ſaid to make of it, ſeems, if true, very ſtrange, but having made trial of it my ſelf, by dipping a ſmall piece of it in very good Sallet-oyl,and putting it in my mouth,and then keeping my mouth and noſe under water,I could not find any ſuch thing; for I

was as ſoon out of breath,as if I had had no Sponge,nor could I fetch my breath without taking in water at my mouth; but I am very apt to think, that were there a contrivance whereby the expir'd air might be forc'd to paſs through a wet or oyly Sponge before it were again inſpir'd, it might much cleanſe, and ſtrain away from the Air divers fuliginous and other noiſome ſteams, and the dipping of it in certain liquors might, perhaps, ſo renew that property in the Air which it loſes in the Lungs,by being breath'd, that one ſquare foot of Air might laſt a man for reſpiration much longer, perhaps,then ten will now ſerve him of common Air.

Obſerv. XXIII. *Of the curious texture of* Sea-weeds.

FOr curioſity and beauty, I have not among all the Plants or Vegetables I have yet obſerv'd, ſeen any one comparable to this Sea-weed I have here deſcrib'd, of which I am able to ſay very little more then what is repreſented by the ſecond *Figure* of the ninth *Scheme*: Namely, that it is a Plant which grows upon the Rocks under the water, and increaſes and ſpreads it ſelf into a great tuft, which is not onely handſomely branch'd into ſeveral leaves, but the whole ſurface of the Plant is cover'd over with a moſt curious kind of carv'd work, which conſiſts of a texture much reſembling a Honey-comb; for the whole ſurface on both ſides is cover'd over with a multitude of very ſmall holes,being no bigger then ſo many holes made with the point of a ſmall Pinn, and rang'd in the neateſt and moſt delicate order imaginable, they being plac'd in the manner of a *Quincunx*, or very much like the rows of the eyes of a Fly, the rows or orders being very regular, which way ſoever they are obſerv'd: what the texture was, as it appear'd through a pretty bigg Magnifying *Microſcope*, I have here adjoin'd in the firſt *Figure* of the 14. *Scheme*. which round Area A B C D repreſents a part of the ſurface about one eighth part of an Inch in Diameter: Thoſe little holes, which to the eye look'd round, like ſo many little ſpots, here appear'd very regularly ſhap'd holes, repreſenting almoſt the ſhape of the ſole of a round toed ſhoe, the hinder part of which, is, as it were, trod on or cover'd by the toe of that next below it;theſe holes ſeem'd wall'd about with a very thin and tranſparent ſubſtance, looking of a pale ſtraw-colour; from the edge of which, againſt the middle of each hole, were ſprouted out four ſmall tranſparent ſtraw-colour'd Thorns, which ſeem'd to protect and cover thoſe cavities, from either ſide two; neer the root of this Plant, were ſprouted out ſeveral ſmall branches of a kind of baſtard *Coralline*, curiouſly branch'd, though ſmall.

And to confirm this, having lately the opportunity of viewing the large Plant (if I may ſo call it) of a Sponge *petrify'd*, of which I made mention in the laſt Obſervation, I found, that each of the Branches or Figures of it, did, by the range of its pores, exhibit juſt ſuch a texture,

the

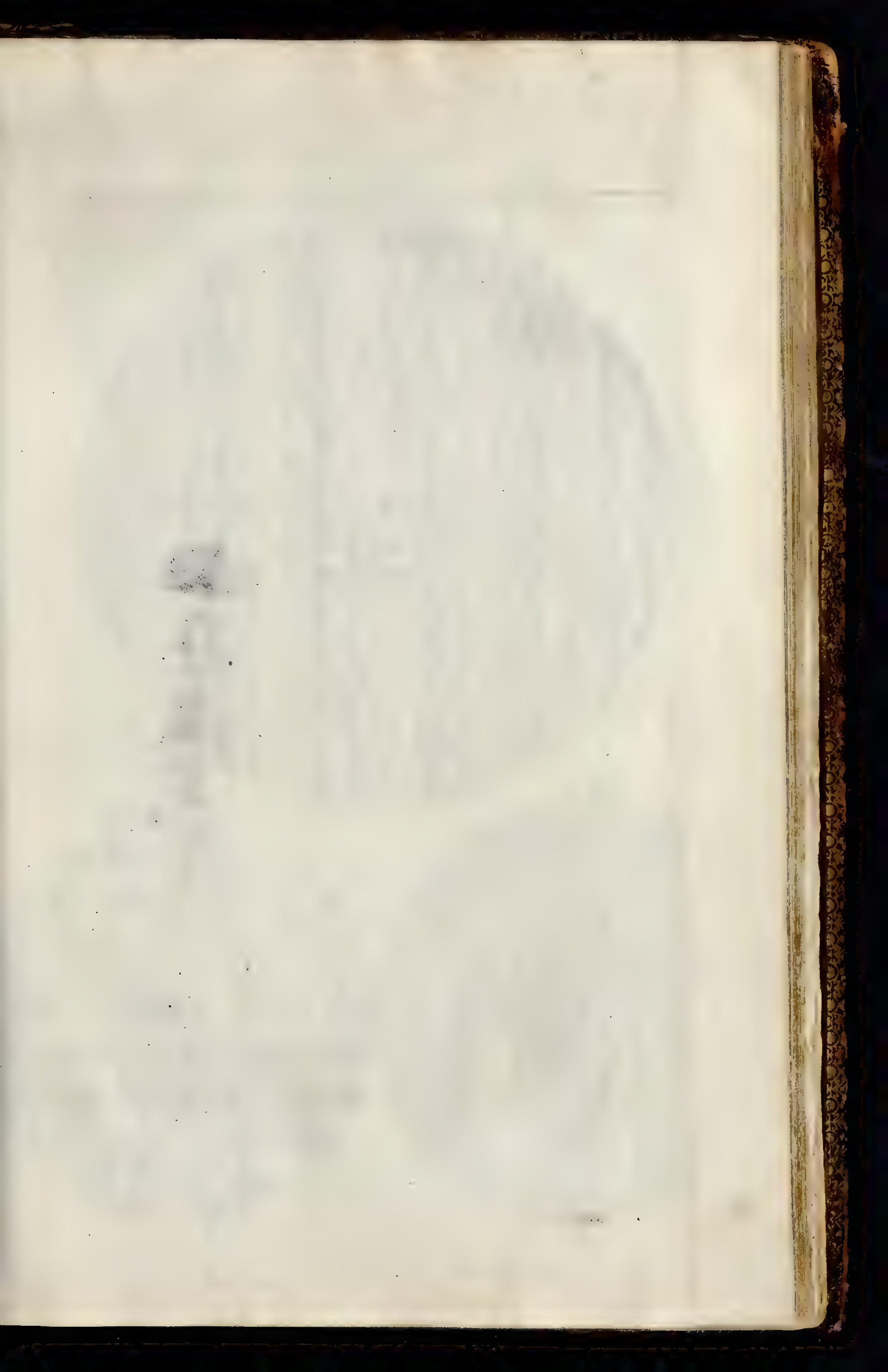


Fig: 1.

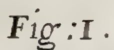


Fig. 2.

Fig: 3.

the rows of pores crossing one another, much after the manner as the rows of eyes do which are describ'd in the 26. *Scheme*: *Coralline* also, and several sorts of white *Coral*, I have with a *Microscope* observ'd very curiously shap'd. And I doubt not, but that he that shall observe these several kinds of Plants that grow upon Rocks, which the Sea sometimes overflows, and those heaps of others which are vomited out of it upon the shore, may find multitudes of little Plants, and other bodies, which like this will afford very beautifull objects for the *Microscope*; and this *Specimen* here is adjoin'd onely to excite their curiosities who have opportunity of observing to examine and collect what they find worthy their notice; for the Sea, among terrestrial bodies, is also a *prolifick* mother, and affords as many Instances of *spontaneous* generations as either the Air or Earth.

Observ. XXIV. *Of the surfaces of* Rosemary, *and other leaves.*

THis which is delineated within the circle of the second *Figure* of the 14. *Scheme*, is a small part of the back or under side of a leaf of Rosemary, which I did not therefore make choice of, because it had any thing peculiar which was not observable with a *Microscope* in several other Plants, but because it exhibits at one view,

First, a smooth and shining surface, namely, A B, which is a part of the upper side of the leaf, that by a kind of hem or doubling of the leaf appears on this side. There are multitudes of leaves, whose surfaces are like this smooth, and as it were quilted, which look like a curious quilted bagg of green Silk, or like a Bladder, or some such pliable transparent substance, full stuffed out with a green juice or liquor; the surface of Rue, or Herbgrass, is polish'd, and all over indented, or pitted, like the Silk-worm's Egg, which I shall anon describe; the smooth surfaces of other Plants are otherwise quilted, Nature in this, as it were, expressing her Needle-work, or imbroidery.

Next a downy or bushy surface, such as is all the under side almost, appearing through the *Microscope* much like a thicket of bushes, and with this kind of Down or Hair the leaves and stalks of multitudes of Vegetables are covered; and there seems to be as great a variety in the shape, bulk, and manner of the growing of these secundary Plants, as I may call them (they being, as it were, a Plant growing out of a Plant, or somewhat like the hairs of Animals) as there is to be found amongst small shrubs that compose bushes; but for the most part, they consist of small transparent parts, some of which grow in the shape of small Needles or Bodkins, as on the Thistle, Cowag-ecod and Nettle; others in the form of Cat's claws, as in Cliders, the beards of Barley, the edges of several sorts of Grass and Reeds, *&c.* in other, as Coltsfoot, Rose-campion, Aps, Poplar, Willow, and almost all other downy Plants, they grow in the form of bushes very much diversify'd in each particular Plant. That which I have before

before in the 19. Obſervation noted on Roſe-leaves, is of a quite differing kind, and ſeems indeed a real Vegetable, diſtinct from the leaf.

Thirdly, among theſe ſmall buſhes are obſervable an infinite company of ſmall round Balls, exactly Globular, and very much reſembling Pearls, namely, CCCC, of theſe there may be multitudes obſerv'd in Sage, and ſeveral other Plants, which I ſuppoſe was the reaſon why *Athanaſius Kircher* ſuppoſed them to be all cover'd with Spiders Eggs, or young Spiders, which indeed is nothing elſe but ſome kind of gummous exſudation, which is always much of the ſame bigneſs. At firſt ſight of theſe, I confeſs, I imagin'd that they might have been ſome kind of *matrices*, or nouriſhing receptacles for ſome ſmall Inſect, juſt as I have found Oak-apples, and multitudes of ſuch other large excreſcencies on the leaves and other parts of Trees and ſhrubs to be for Flyes, and divers other Inſects, but obſerving them to be there all the year, and ſcarce at all to change their magnitude, that conjecture ſeem'd not ſo probable. But what ever be the uſe of it, it affords a very pleaſant object through the *Microſcope*, and may, perhaps, upon further examination, prove very luciferous.

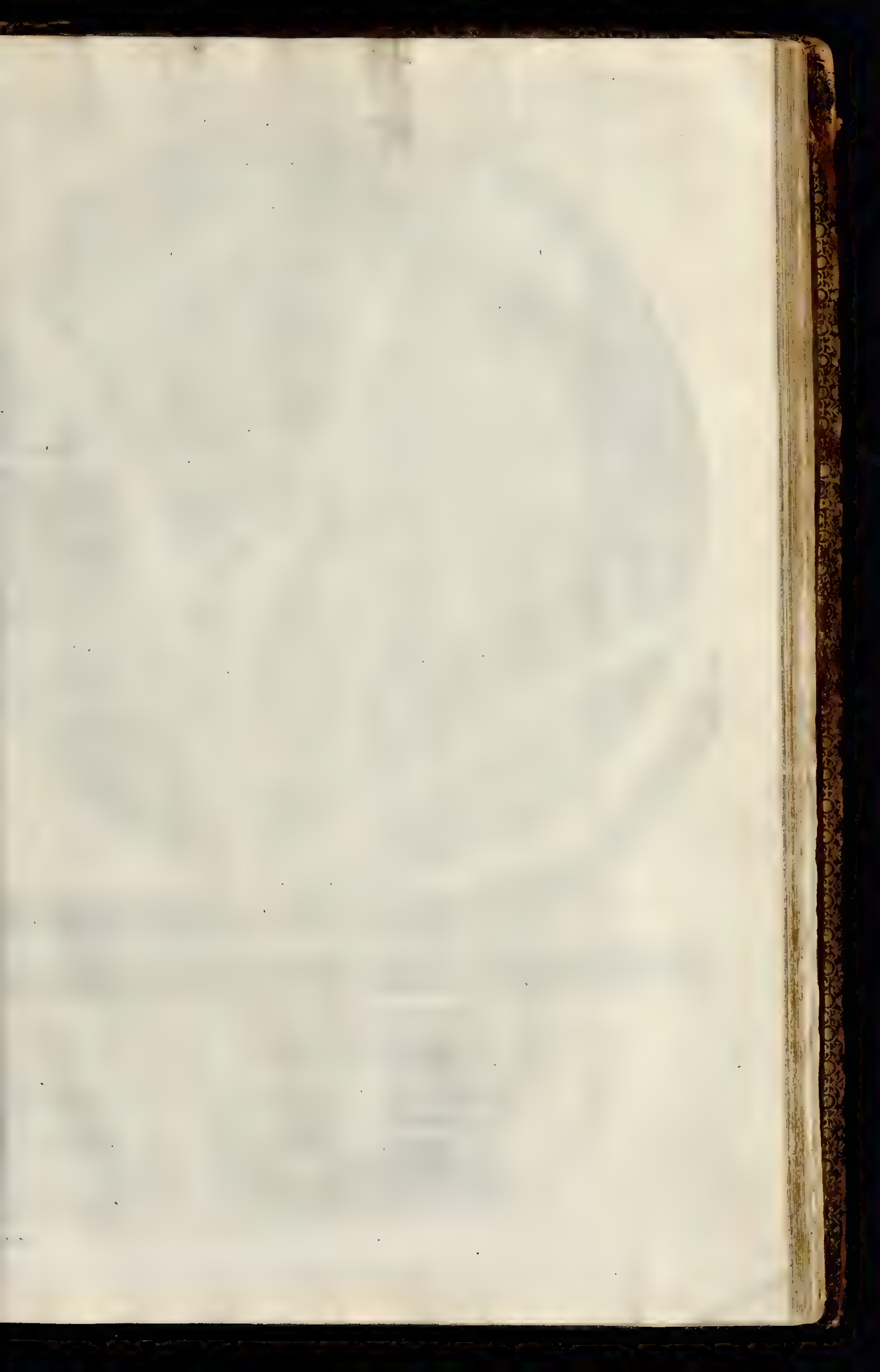
Obſerv. XXV. *Of the ſtinging points and juice of* Nettles, *and ſome other venomous Plants.*

A Nettle is a Plant ſo well known to every one, as to what the appearance of it is to the naked eye, that it needs no deſcription; and there are very few that have not felt as well as ſeen it; and therefore it will be no news to tell that a gentle and ſlight touch of the ſkin by a Nettle, does oftentime, not onely create very ſenſible and acute pain, much like that of a burn or ſcald, but often alſo very angry and hard ſwellings and inflamations of the parts, ſuch as will preſently riſe, and continue ſwoln divers hours. Theſe obſervations, I ſay, are common enough; but how the pain is ſo ſuddenly created, and by what means continued, augmented for a time, and afterwards diminiſh'd, and at length quite exſtinguiſh'd, has not, that I know, been explain'd by any.

And here we muſt have recourſe to our *Microſcope*, and that will, if almoſt any part of the Plant be looked on, ſhew us the whole ſurface of it very thick ſet with turn-Pikes, or ſharp Needles, of the ſhape of thoſe repreſented in the 15. *Scheme* and firſt *Figure* by A B, which are viſible alſo to the naked eye; each of which conſiſts of two parts very diſtinct for ſhape, and differing alſo in quality from one another. For the part A, is ſhaped very much like a round Bodkin, from B tapering till it end in a very ſharp point; it is of a ſubſtance very hard and ſtiff, exceedingly tranſparent and cleer, and, as I by many trials certainly found, is hollow from top to bottom.

This I found by this Experiment, I had a very convenient *Micro-*

ſcope




Schem.X
Fig:1.
Fig:2.
Fig:3.
Fig:4.

ſcope with a ſingle Glaſs which drew about half an Inch, this I had faſtned into a little frame, almoſt like a pair of Spectacles, which I placed before mine eyes, and ſo holding the leaf of a Nettle at a convenient diſtance from my eye, I did firſt, with the thruſting of ſeveral of theſe briſtles into my ſkin, perceive that preſently after I had thruſt them in I felt the burning pain begin; next I obſerv'd in divers of them, that upon thruſting my finger againſt their tops, the Bodkin (if I may ſo call it) did not in the leaſt bend, but I could perceive moving up and down within it a certain liquor, which upon thruſting the Bodkin againſt its baſis, or bagg B, I could perceive to riſe towards the top, and upon taking away my hand, I could ſee it again ſubſide, and ſhrink into the bagg; this I did very often, and ſaw this *Phænomenon* as plain as I could ever ſee a parcel of water aſcend and deſcend in a pipe of Glaſs. But the baſis underneath theſe Bodkins on which they were faſt, were made of a more pliable ſubſtance, and looked almoſt like a little bagg of green Leather, or rather reſembled the ſhape and ſurface of a wilde Cucumber, or *cucumeris aſinini*, and I could plainly perceive them to be certain little baggs, bladders, or receptacles full of water, or as I gheſs, the liquor of the Plant, which was poiſonous, and thoſe ſmall Bodkins were but the Syringe-pipes, or Glyſter-pipes, which firſt made way into the ſkin, and then ſerved to convey that poiſonous juice, upon the preſſing of thoſe little baggs, into the interior and ſenſible parts of the ſkin, which being ſo diſcharg'd, does corrode, or, as it were, burn that part of the ſkin it touches; and this pain will ſometimes laſt very long, according as the impreſſion is made deeper or ſtronger.

The other parts of the leaf or ſurface of the Nettle, have very little conſiderable, but what is common to moſt of theſe kinds of Plants, as the ruggedneſs or indenting, and hairineſs, and other roughneſſes of the ſurface or out-ſide of the Plant, of which I may ſay more in another place. As I ſhall likewiſe of certain little pretty cleer Balls or Apples which I have obſerved to ſtick to the ſides of theſe leaves, both on the upper and under ſide, very much like the ſmall Apples which I have often obſerv'd to grow on the leaves of an Oak call'd *Oak-apples* which are nothing but the *Matrices* of an Inſect, as I elſewhere ſhew.

The chief thing therefore is, how this Plant comes, by ſo ſlight a touch, to create ſo great a pain; and the reaſon of this ſeems to be nothing elſe, but the corroſive penetrant liquor contain'd in the ſmall baggs or bladders, upon which grow out thoſe ſharp Syringe-pipes, as I before noted; and very conſonant to this, is the reaſon of the pain created by the ſting of a Bee, Waſp, *&c.* as I elſewhere ſhew: For by the Dart, which is likewiſe a pipe, is made a deep paſſage into the ſkin, and then by the anger of the Fly, is his gally poiſonous liquor injected; which being admitted among the ſenſible parts, and ſo mix'd with the humours or *ſtagnating* juices of that part, does create an Ebullition perhaps, or *efferveſcens*, as is uſually obſerv'd in the mingling of two differing *Chymical ſaline* liquors, by which means the parts become ſwell'd, hard, and very painfull; for thereby the nervous and ſenſible parts are not onely ſtretch'd and ſtrain'd

beyond

beyond their natural *tone*, but are alſo prick'd, perhaps, or corroded by the pungent and incongruous pores of the intruded liquor.

And this ſeems to be the reaſon, why *Aqua fortis*, and other *ſaline* liquors, if they come to touch the ſenſitive parts, as in a cut of the ſkin, or the like, do ſo violently and intollerably *excruciate* and torment the Patient. And 'tis not unlikely, but the Inventors of that Diabolical practice of poiſoning the points of Arrows and Ponyards, might receive their firſt hint from ſome ſuch Inſtance in natural contrivances, as this of the Nettle: for the ground why ſuch poiſon'd weapons kill ſo infallibly as they do, ſeems no other then this of our Nettle's ſtinging; for the Ponyard or Dart makes a paſſage or entrance into the ſenſitive or vital parts of the body, whereby the contagious ſubſtance comes to be diſſolv'd by, and mix'd with the fluid parts or humours of the body, and by that means ſpreads it ſelf by degrees into the whole liquid part of the body, in the ſame manner, as a few grains of Salt, put into a great quantity of Water, will by degrees diffuſe it ſelf over the whole.

And this I take to be the reaſon of killing of Toads, Frogs, Effs, and ſeveral Fiſhes, by ſtrewing Salt on their backs (which Experiment was ſhewn to the *Royal Society* by a very ingenious Gentleman, and a worthy Member of it) for thoſe creatures having always a continual exſudation, as it were, of ſlimy and watry parts, ſweating out of the pores of their ſkin, the *ſaline* particles, by that means obtain a *vehicle*, which conveys them into the internal and vital parts of the body.

This ſeems alſo to be the reaſon why bathing in Mineral waters are ſuch ſoveraign remedies for multitudes of diſtempers, eſpecially chronical; for the liquid & warm *vehicles* of the Mineral particles, which are known to be in very conſiderable quantities in thoſe healing baths, by the body's long ſtay in them, do by degrees ſteep and inſinuate themſelves into the pores and parts of the ſkin, and thereby thoſe Mineral particles have their ways and paſſages open'd to penetrate into the inner parts, and mingle themſelves with the *ſtagnant* juices of the ſeveral parts; beſides, many of thoſe offenſive parts which were united with thoſe *ſtagnant* juices, and which were contrary to the natural conſtitution of the parts, and ſo become irkſome and painfull to the body, but could not be diſcharged, becauſe Nature had made no proviſion for ſuch accidental miſchiefs, are, by means of this ſoaking, and filling the pores of the ſkin with a liquor, afforded a paſſage through that liquor that fills the pores into the ambient fluid, and thereby the body comes to be diſcharged.

So that 'tis very evident, there may be a good as well as an evil application of this Principle. And the ingenious Invention of that Excellent perſon, Doctor *Wren*, of injecting liquors into the veins of an Animal, ſeems to be reducible to this head: I cannot ſtay, nor is this a fit place, to mention the ſeveral Experiments made of this kind by the moſt incomparable Mr. *Boyle*, the multitudes made by the lately mention'd *Phyſician* Doctor *Clark*, the Hiſtory whereof, as he has been pleas'd to communicate to the *Royal Society*, ſo he may perhaps be prevail'd with to make publique himſelf: But I ſhall rather hint, that certainly, if this Principle

were

were well confider'd, there might, befides the further improving of Bathing and Syringing into the veins, be thought on feveral ways, whereby feveral obftinate diftempers of a humane body, fuch as the Gout, Dropfie, Stone, *&c.* might be mafter'd, and expell'd; and good men might make as good a ufe of it, as evil men have made a perverfe and Diabolical.

And that the filling of the pores of the fkin with fome fluid *vehicle*, is of no fmall efficacy towards the preparing a paffage for feveral kinds of penetrant juices, and other diffoluble bodies, to infinuate themfelves within the fkin, and into the fenfitive parts of the body, may be, I think, prov'd by an Inftance given us by *Bellonius*, in the 26. *Chapter* of the fecond Book of his *Obfervations*, which containing a very remarkable Story I have here tranfcrib'd: *Cum Chamæleonis nigri radices* (fays he) *apud Pagum quendam Livadochorio nuncupatum erui curaremus, plurimi Græci & Turcæ fpectatum venerunt quid erueremus, eas vero fruftulatim fecabamus, & filo trajiciebamus ut facilius exficcari poffent. Turcæ in eo negotio occupatos nos videntes, fimiliter eas radices tractare & fecare voluerunt: at cum fummus effet æftus, & omnes fudore maderent, quicunque eam radicem manibus tractaverant fudoremque abfterferant, aut faciem digitis fcalpferant, tantam pruriginem iis locis quos attigerant poftea fenferunt, ut aduri viderentur. Chamæleonis enim nigri radix ea virtute pollet, ut cuti applicata ipfam adeo inflammet, ut nec fquillæ, nec urticæ ullæ centefima parte ita adurent: At prurigo non adeo celeriter fefe prodit. Poft unam aut alteram porro horam, finguli variis faciei locis cutem adeo inflammatam habere cæpimus ut tota fanguinea videretur, atque quo magis eam confricabamus, tanto magis excitabatur prurigo. Fonti affidebamus fub platano, atque initio pro ludicro habebamus & ridebamus: at tandem illi plurimum indignati funt, & nifi affeveraffemus nunquam expertos tali virtute eam plantam pollere, haud dubie male nos multaffent. Attamen noftra excufatio fuit ab illis facilius accepta, cum eodem incommodo nos affectos confpicerent. Mirum fane quod in tantillo radice tam ingentem efficaciam noftro malo experti fumus.*

By which obfervation of his, it feems manifeft, that their being all cover'd with fweat who gather'd and cut this root of the black *Chameleon* Thiftle, was the great reafon why they fuffer'd that inconvenience, for it feems the like circumftance had not been before that noted, nor do I find any mention of fuch a property belonging to this Vegetable in any of the Herbals I have at prefent by me.

I could give very many Obfervations which I have made of this kind, whereby I have found that the beft way to get a body to be infinuated into the fubftance or infenfible pores of another, is firft, to find a fluid *vehicle* that has fome congruity, both to the body to be infinuated, and to the body into whofe pores you would have the other convey'd. And in this Principle lies the great myftery of ftaining feveral forts of bodies, as Marble, Woods, Bones, *&c.* and of Dying Silks, Cloaths, Wools, Feathers, *&c.* But thefe being digreffions, I fhall proceed to:

Obferv. XXVI. *Of* Cowage, *and the itching operation of fome bodies.*

THere is a certain Down of a Plant, brought from the *Eaft-Indies*, call'd commonly, though very improperly, *Cow-itch*, the reafon of which

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miſtake is manifeſt enough from the deſcription of it, which Mr. *Parkinſon* ſets down in his *Herbal*, Tribe XI. Chap. 2. *Phaſiolus ſiliqua hirſuta*; *The hairy Kidney-bean, called in* Zurratte *where it grows*, *Couhage: We have had* (ſays he) *another of this kind brought us out of the* Eaſt-Indies, *which being planted, was in ſhew like the former, but came not to perfection, the unkindly ſeaſon not ſuffering it to ſhew the flower; but of the Cods that were brought, ſome were ſmaller, ſhorter, and rounder then the Garden kind; others much longer, and many growing together, as it were in cluſters, and cover'd all over with a brown ſhort hairineſs, ſo fine, that if any of it be rubb'd, or fall on the back of ones hand, or other tender parts of the skin, it will cauſe a kind of itching, but not ſtrong, nor long induring, but paſſing quickly away, without either danger or harm; the Beans were ſmaller then ordinary, and of a black ſhining colour.*

Having one of theſe Cods given me by a Sea-Captain, who had frequented thoſe parts, I found it to be a ſmall Cod, about three Inches long, much like a ſhort Cod of *French Beans*, which had ſix Beans in it, the whole ſurface of it was cover'd over with a very thick and ſhining brown Down or Hair, which was very fine, and for its bigneſs ſtiff; taking ſome of this Down, and rubbing it on the back of my hand, I found very little or no trouble, only I was ſenſible that ſeveral of theſe little downy parts with rubbing did penetrate, and were ſunk, or ſtuck pretty deep into my ſkin. After I had thus rubb'd it for a pretty while, I felt very little or no pain, in ſo much that I doubted, whether it were the true Couhage; but whil'ſt I was conſidering, I found the Down begin to make my hand itch, and in ſome places to ſmart again, much like the ſtinging of a Flea or Gnat, and this continued a pretty while, ſo that by degrees I found my ſkin to be ſwell'd with little red puſtules, and to look as if it had been itchie. But ſuffering it without rubbing or ſcratching, the itching tickling pain quickly grew languid, and within an hour I felt nothing at all, and the little *protuberancies* were vaniſh'd.

The cauſe of which odd *Phænomenon*, I ſuppoſe to be much the ſame with that of the ſtinging of a Nettle, for by the *Microſcope*, I diſcover'd this Down to conſiſt of a multitude of ſmall and ſlender conical bodies, much reſembling Needles or Bodkins, ſuch as are repreſented by A B. C D. E F. of the firſt Figure of the XVI. *Scheme*; that their ends A A A, were very ſharp, and the ſubſtance of them ſtiff and hard, much like the ſubſtance of ſeveral kinds of Thorns and crooks growing on Trees. And though they appear'd very cleer and tranſparent, yet I could not perceive whether they were hollow or not, but to me they appear'd like ſolid tranſparent bodies, without any cavity in them; whether, though they might not be a kind of Cane, fill'd with ſome tranſparent liquor which was hardned (becauſe the Cod which I had was very dry) I was not able to examine.

Now, being ſuch ſtiff, ſharp bodies, it is eaſie to conceive, how with rubbing they might eaſily be thruſt into the tender parts of the skin, and there, by reaſon of their exceeding fineneſs and drineſs, not create any conſiderable trouble or pain, till by remaining in thoſe places moiſtned with the humours of the body, ſome cauſtick part ſticking on them, or

reſiding

residing within them might be dissolv'd and mix'd with the ambient juices of that place, and thereby those *fibres* and tender parts adjoyning become affected, and as it were corroded by it; whence, while that action lasts, the pains created are pretty sharp and pungent, though small, which is the essential property of an itching one.

That the pain also caused by the stinging of a Flea, a Gnat, a Flie, a Wasp, and the like, proceeds much from the very same cause, I elsewhere in their proper places endeavour to manifest. The stinging also of shred Horse-hair, which in meriment is often strew'd between the sheets of a Bed, seems to proceed from the same cause.

Observ. XXVII. *Of the* Beard *of a wilde* Oat, *and the use that may be made of it for exhibiting always to the Eye the temperature of the Air, as to driness and moisture.*

THis Beard of a wild *Oat*, is a body of a very curious structure, though to the naked Eye it appears very slight, and inconsiderable, it being only a small black or brown Beard or Bristle, which grows out of the side of the inner Husk that covers the Grain of a wild *Oat*; the whole length of it, when put in Water, so that it may extend it self to its full length, is not above an Inch and a half, and for the most part somewhat shorter, but when the Grain is ripe, and very dry, which is usualy in the Moneths of *July*, and *August*, this Beard is bent somewhat below the middle, namely, about ⅓ from the bottom of it, almost to a right Angle, and the under part of it is wreath'd lik a With; the substance of it is very brittle when dry, and it will very easily be broken from the husk on which it grows.

If you take one of these Grains, and wet the Beard in Water, you will presently see the small bended top to turn and move round, as if it were sensible; and by degrees, if it be continued wet enough, the joint or knee will streighten it self; and if it be suffer'd to dry again, it will by degrees move round another way, and at length bend again into its former posture.

If it be view'd with an ordinary single *Microscope*, it will appear like a small wreath'd Sprig, with two clefts; and if wet as before, and then look'd on with this *Microscope*, it will appear to unwreath it self, and by degrees, to streighten its knee, and the two clefts will become streight, and almost on opposite sides of the small cylindrical body.

If it be continued to be look'd a little longer with a *Microscope*, it will within a little while begin to wreath it self again, and soon after return to its former posture, bending it self again neer the middle, into a kind of knee or angle.

Several of those bodies I examin'd with larger *Microscopes*, and there found them much of the make of those two long wreath'd cylinders delineated in the second Figure of the 15. *Scheme*, which two cylinders re-

present the wreathed part broken into two pieces,whereof the end A B is to be suppos'd to have join'd to the end C D, so that E A C F does represent the whole wreath'd part of the Beard, and E G a small piece of the upper part of the Beard which is beyond the knee, which as I had not room to insert, so was it not very considerable, either for its form,or any known property; but the under or wreathed part is notable for both: As to its form, it appear'd, if it were look'd on side-ways, almost like a Willow, or a small tapering rod of *Hazel*, the lower or bigger half of which onely, is twisted round several times,in some three, in others more, in others less, according to the bigness and maturity of the Grain on which it grew, and according to the driness and moisture of the ambient Air, as I shall shew more at large by and by.

The whole outward Superficies of this Cylindrical body is curiously adorned or fluted with little channels, and interjacent ridges, or little *protuberances* between them, which run the whole length of the Beard, and are streight where the Beard is not twisted,and wreath'd where it is, just after the same manner: each of those sides is beset pretty thick with small Brisles or Thorns, somewhat in form resembling that of *Porcupines* Quills, such as *a a a a a* in the Figure; all whose points are directed like so many Turn-pikes towards the small end or top of the Beard, which is the reason, why, if you endeavour to draw the Beard between your fingers the contrary way, you will find it to stick, and grate, as it were, against the skin.

The proportion of these small conical bodies *a a a a a* to that whereon they grow, the Figure will sufficiently shew, as also their manner of growing,their thickness, and neerness to each other, as, that towards the root or bottom of the Beard, they are more thin, and much shorter,insomuch that there is usually left between the top of the one, and the bottom of that next above it, more then the length of one of them, and that towards the top of the Beard they grow more thick and close (though there be fewer ridges) so that the root, and almost half the upper are hid by the tops of those next below them.

I could not perceive any *transverse* pores, unless the whole wreath'd part were separated and cleft,in those little channels,by the wreathing into so many little strings as there were ridges, which was very difficult to determine; but there were in the wreathed part two very conspicuous channels or clefts, which were continued from the bottom F to the elbow E H, or all along the part which was wreath'd, which seem'd to divide the wreath'd Cylinder into two parts, a bigger and a less; the bigger was that which was at the *convex* side of the knee, namely, on the side A, and was wreath'd by O O O O O; this, as it seem'd the broader, so did it also the longer, the other P P P P P, which was usually purs'd or wrinckled in the bending of the knee,as about E, seem'd both the shorter and narrower, so that at first I thought the wreathing and unwreathing of the Beard might have been caus'd by the shrinking or swelling of that part; but upon further examination,I found that the clefts, K K, L L,were stuft up with a kind of Spohgie substance, which, for the most part, was very

very conſpicuous neer the knee, as in the cleft K K, when the Beard was dry ; upon the diſcovery of which, I began to think, that it was upon the ſwelling of this porous pith upon the acceſs of moiſture or water that the Beard, being made longer in the midſt, was ſtreightned, and by the ſhrinking or ſubſiding of the parts of that Spongie ſubſtance together, when the water or moiſture was exhal'd or dried, the pith or middle parts growing ſhorter, the whole became twiſted.

But this I cannot be poſitive in, for upon cutting the wreath'd part in many places tranſverſly, I was not ſo well ſatisfy'd with the ſhape and manner of the pores of the pith ; for looking on theſe tranſverſe Sections with a very good *Microſcope*, I found that the ends of thoſe tranſverſe Sections appear'd much of the manner of the third Figure of the 15. *Scheme* A B C F E, and the middle or pith C C, ſeem'd very full of pores indeed, but all of them ſeem'd to run the long-ways.

This Figure plainly enough ſhews in what manner thoſe clefts, K and L divided the wreath'd Cylinder into two unequal parts, and alſo of what kind of ſubſtance the whole body conſiſts ; for by cutting the ſame Beard in many places, with tranſverſe Sections, I found much the ſame appearance with this expreſs'd ; ſo that thoſe pores ſeem to run, as in moſt other ſuch Cany bodies, the whole length of it.

The clefts of this body K K, and L L, ſeem'd (as is alſo expreſs'd in the Figure) to wind very oddly in the inner part of the wreath ; and in ſome parts of them, they ſeem'd ſtuffed, as it were, with that Spongie ſubſtance, which I juſt now deſcribed.

This ſo oddly conſtituted Vegetable ſubſtance, is firſt (that I have met with) taken notice of by *Baptiſta Porta*, in his *Natural Magick*, as a thing known to children and Juglers, and it has been call'd by ſome of thoſe laſt named perſons, the better to cover their cheat, the Legg of an *Arabian Spider*, or the Legg of an inchanted *Egyptian Fly*, and has been uſed by them to make a ſmall Index, Croſs, or the like, to move round upon the wetting of it with a drop of Water, and muttering certain words.

But the uſe that has been made of it, for the diſcovery of the various conſtitutions of the Air, as to drineſs and moiſtneſs, is incomparably beyond any other ; for this it does to admiration : The manner of contriving it ſo, as to perform this great effect, is onely thus :

Provide a good large Box of Ivory, about four Inches over, and of what depth you ſhall judge convenient (according to your intention of making uſe of one, two, three, or more of theſe ſmall Beards, ordered in the manner which I ſhall by and by deſcribe) let all the ſides of this Box be turned of Baſket-work (which here in *London* is eaſily enough procur'd) full of holes, in the manner almoſt of a Lettice, the bigger, or more the holes are, the better, that ſo the Air may have the more free paſſage to the incloſed Beard, and may the more eaſily paſs through the Inſtrument ; it will be better yet, though not altogether ſo handſom, if inſteed of the Baſket-work on the ſides of the Box, the bottom and top of the Box be join'd together onely with three or four ſmall Pillars, after the manner repre-

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ſented in the 4.Figure of the 15. *Scheme.* Or,if you intend to make uſe of many of theſe ſmall Beards join'd together, you may have a ſmall long Caſe of Ivory, whoſe ſides are turn'd of Baſket-work, full of holes, which may be ſcrew'd on to the underſide of a broad Plate of Ivory,on the other ſide of which is to be made the divided Ring or Circle, to which diviſions the pointing of the Hand or Index, which is moved by the conjoin'd Beard, may ſhew all the *Minute* variations of the Air.

There may be multitudes of other ways for contriving this ſmall Inſtrument, ſo as to produce this effect, which any one may, according to his peculiar uſe, and the exigency of his preſent occaſion, eaſily enough contrive and take, on which I ſhall not therefore inſiſt. The whole manner of making any one of them is thus: Having your Box or frame A A B B, fitly adapted for the free paſſage of the Air through it,in the midſt of the bottom B B B, you muſt have a very ſmall hole C, into which the lower end of the Beard is to be fi'xd,the upper end of which Beard *a b*,is to paſs through a ſmall hole of a Plate, or top A A, if you make uſe onely of a ſingle one, and on the top of it *e*, is to be fix'd a ſmall and very light *Index f g*, made of a very thin ſliver of a Reed or Cane ; but if you make uſe of two or more Beards, they muſt be fix'd and bound together, either with a very fine piece of Silk, or with a very ſmall touch of hard Wax, or Glew,which is better, and the *Index f g*, is to be fix'd on the top of the ſecond,third, or fourth in the ſame manner as on the ſingle one.

Now, becauſe that in every of theſe contrivances, the *Index f g*, will with ſome temperatures of Air, move two, three, or more times round, which without ſome other contrivance then this,will be difficult to diſtinguiſh,therefore I thought of this Expedient: The *Index* or *Hand f g*, being rais'd a pretty way above the ſurface of the Plate A A, fix in at a little diſtance from the middle of it a ſmall Pin *h*, ſo as almoſt to touch the ſurface of the Plate A A, and then in any convenient place of the ſurface of the Plate,fix a ſmall Pin, on which put on a ſmall piece of Paper, or thin Paſt-board, Vellom, or Parchment, made of a convenient cize, and ſhap'd in the manner of that in the Figure expreſs'd by *i k*, ſo that having a convenient number of teeth every turn or return of the Pin *h*, may move this ſmall indented Circle, a tooth forward or backwards, by which means the teeth of the Circle, being mark'd, it will be thereby very eaſie to know certainly, how much variation any change of weather will make upon the ſmall wreath'd body. In the making of this Secundary Circle of Vellom, or the like, great care is to be had, that it be made exceeding light, and to move very eaſily, for otherwiſe a ſmall variation will ſpoil the whole operation. The Box may be made of Braſs, Silver, Iron, or any other ſubſtance, if care be taken to make it open enough, to let the Air have a ſufficiently free acceſs to the Beard. The *Index* alſo may be various ways contrived, ſo as to ſhew both the number of the revolutions it makes, and the *Minute* diviſions of each revolution.

I have made ſeveral trials and Inſtruments for diſcovering the drineſs and moiſture of the Air with this little wreath'd body,and find it to vary exceeding ſenſibly with the leaſt change in the conſtitution of the Air, as

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to drineſs and moiſture, ſo that with one breathing upon it, I have made it untwiſt a whole bout, and the *Index* or *Hand* has ſhew'd or pointed to various diviſions on the upper Face or Ring of the Inſtrument, according as it was carried neerer and neerer to the fire, or as the heat of the Sun increaſed upon it.

Other trials I have made with Gut-ſtrings,but find them nothing neer ſo ſenſible, though they alſo may be ſo contriv'd as to exhibit the changes of the Air, as to drineſs and moiſture, both by their ſtretching and ſhrinking in length, and alſo by their wreathing and unwreathing themſelves; but theſe are nothing neer ſo exact or ſo tender;for their varying property will in a little time change very much. But there are ſeveral other Vegetable ſubſtances that are much more ſenſible then even this Beard of a wilde *Oat*; ſuch I have found the Beard of the ſeed of Muſk-graſs, or *Geranium moſchatum*, and thoſe of other kinds of *Cranes-bil* ſeeds, and the like. But always the ſmaller the wreathing ſubſtance be, the more ſenſible is it of the mutations of the Air, a conjecture at the reaſon of which I ſhall by and by add.

The lower end of this wreath'd Cylinder being ſtuck upright in a little ſoft Wax, ſo that the bended part or *Index* of it lay *horizontal*, I have obſerv'd it always with moiſture to unwreath it ſelf from the Eaſt (For inſtance)by the South to the Weſt,and ſo by the North to the Eaſt again, moving with the Sun (as we commonly ſay) and with heat and drouth to re-twiſt, and wreath it ſelf the contrary way, namely, from the Eaſt, (for inſtance) by the North to the Weſt, and ſo onwards.

The cauſe of all which *Phænomena*, ſeems to be the differing texture of the parts of theſe bodies, each of them (eſpecially the Beard of a wilde *Oat*, and of *Mosk-graſs* ſeed) ſeeming to have two kind of ſubſtances,one that is very porous,looſe,and ſpongie,into which the watry ſteams of the Air may be very eaſily forced,which will be thereby ſwell'd and extended in its dimenſions, juſt as we may obſerve all kind of Vegetable ſubſtance upon ſteeping in water to ſwell and grow bigger and longer. And a ſecond that is more hard and cloſe,into which the water can very little,or not at all penetrate, this therefore retaining always very neer the ſame dimenſions, and the other ſtretching and ſhrinking, according as there is more or leſs moiſture or water in its pores, by reaſon of the make and ſhape of the parts, the whole body muſt neceſſarily unwreath and wreath it ſelf.

And upon this Principle, it is very eaſie to make ſeveral ſorts of contrivances that ſhould thus wreath and unwreath themſelves, either by heat and cold, or by drineſs and moiſture, or by any greater or leſs force, from whatever cauſe it proceed, whether from gravity or weight, or from wind which is motion of the Air, or from ſome ſpringing body, or the like.

This, had I time, I ſhould enlarge much more upon; for it ſeems to me to be the very firſt footſtep of *Senſation*, and Animate motion, the moſt plain,ſimple,and obvious contrivance that Nature has made uſe of to produce a motion, next to that of Rarefaction and Condenſation by heat and

and cold. And were this Principle very well examin'd, I am very apt to think, it would afford us a very great help to find out the *Mechanism* of the Muſcles, which indeed, as farr as I have hitherto been able to examine, ſeems to me not ſo very perplex as one might imagine, eſpecially upon the examination which I made of the Muſcles of *Crabs*, *Lobſters*, and ſeveral ſorts of large Shell-fiſh, and comparing my Obſervations on them, with the circumſtances I obſerv'd in the muſcles of terreſtrial Animals.

Now, as in this Inſtance of the Beard of a wilde *Oat*, we ſee there is nothing elſe requiſite to make it wreath and unwreath it ſelf, and to ſtreighten and bend its knee, then onely a little breath of moiſt or dry Air, or a ſmall *atome* almoſt of water or liquor, and a little heat to make it again evaporate; for, by holding this Beard, plac'd and fix'd as I before directed, neer a Fire, and dipping the tip of a ſmall ſhred of Paper in well rectify'd ſpirit of Wine, and then touching the wreath'd *Cylindrical* part, you may perceive it to untwiſt it ſelf; and preſently again, upon the *avolation* of the ſpirit, by the great heat, it will re-twiſt it ſelf, and thus will it move forward and backwards as oft as you repeat the touching it with the ſpirit of Wine; ſo may, perhaps, the ſhrinking and relaxing of the muſcles be by the influx and evaporation of ſome kind of liquor or juice. But of this Enquiry I ſhall add more elſewhere.

Obſerv. XXVIII. *Of the Seeds of* Venus *looking-glaſs, or* Corn *Violet.*

FRom the Leaves, and Downs, and Beards of Plants, we come at laſt to the Seeds; and here indeed ſeems to be the Cabinet of Nature, wherein are laid up its Jewels. The providence of Nature about Vegetables, is in no part manifeſted more, then in the various contrivances about the ſeed, nor indeed is there in any part of the Vegetable ſo curious carvings, and beautifull adornments, as about the ſeed; this in the larger ſorts of ſeeds is moſt evident to the eye; nor is it leſs manifeſt through the *Microſcope*, in thoſe ſeeds whoſe ſhape and ſtructure, by reaſon of their ſmalneſs, the eye is hardly able to diſtinguiſh.

Of theſe there are multitudes, many of which I have obſerv'd through a *Microſcope*, and find, that they do, for the moſt part, every one afford exceeding pleaſant and beautifull objects. For beſides thoſe that have various kinds of carv'd ſurfaces, there are other that have ſmooth and perfectly poliſh'd ſurfaces, others a downy hairy ſurface; ſome are cover'd onely with a ſkin, others with a kind of ſhell, others with both, as is obſervable alſo in greater ſeeds.

Of theſe ſeeds I have onely deſcribed four ſorts which may ſerve as a *Specimen* of what the inquiſitive obſervers are likely to find among the reſt. The firſt of theſe ſeeds which are deſcribed in the 17. *Scheme*, are thoſe of Corn-Violets, the ſeed is very ſmall, black, and ſhining, and, to the naked eye, looks almoſt like a very ſmall Flea; But through the

Microſcope





ous an
table b


Schem XVIII
A
B
D
C
E
G
F
H
I

Microſcope, it appears a large body, cover'd with a tough thick and bright reflecting ſkin very irregularly ſhrunk and pitted, inſomuch that it is almoſt an impoſſibility to find two of them wrinkled alike, ſo great a variety may there be even in this little ſeed.

This, though it appear'd one of the moſt promiſing ſeeds for beauty to the naked eye, yet through the *Microſcope* it appear'd but a rude miſhapen ſeed, which I therefore drew, that I might thereby manifeſt how unable we are by the naked eye to judge of beauteous or leſs curious *microſcopical* Objects; cutting ſome of them in ſunder, I obſerv'd them to be fill'd with a greeniſh yellow pulp, and to have a very thick huſk, in proportion to the pulp.

Obſerv. XXIX. *Of the Seeds of* Tyme.

These pretty fruits here repreſented, in the 18. *Scheme*, are nothing elſe, but nine ſeveral ſeeds of Tyme; they are all of them in differing poſture, both as to the eye and the light; nor are they all of them exactly of the ſame ſhape, there being a great variety both in the bulk and figure of each ſeed; but they all agreed in this, that being look'd on with a *Microſcope*, they each of them exactly reſembled a Lemmon or Orange dry'd; and this both in ſhape and colour. Some of them are a little rounder, of the ſhape of an Orange, as A and B, they have each of them a very conſpicuous part by which they were join'd to their little ſtalk, and one of them had a little piece of ſtalk remaining on; the oppoſite ſide of the ſeed, you may perceive very plainly by the Figure, is very copped and prominent, as is very uſual in Lemmons, which prominencies are expreſs'd in D, E and F.

They ſeem'd each of them a little creas'd or wrinckled, but E was very conſpicuouſly furrow'd, as if the inward make of this ſeed had been ſomewhat like that of a Lemmon alſo, but upon dividing ſeveral ſeeds with a very ſharp Pen-knife, and examining them afterward, I found their make to be in nothing but bulk differing from that of Peas, that is, to have a pretty thick coat, and all the reſt an indifferent white pulp, which ſeem'd very cloſe; ſo that it ſeems Nature does not very much alter her method in the manner of incloſing and preſerving the vital Principle in the ſeed, in theſe very ſmall grains, from that of Beans, Peas, *&c.*

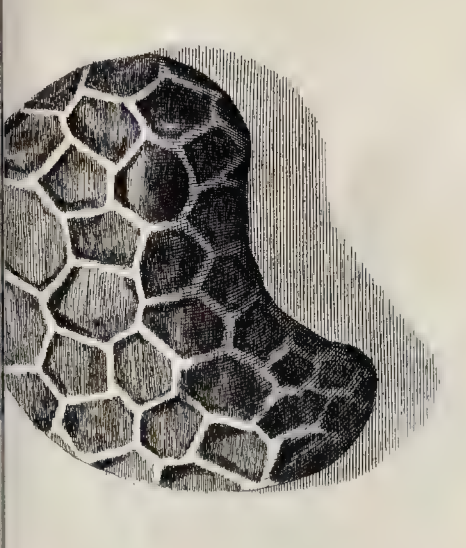
The Grain affords a very pretty Object for the *Microſcope*, namely, a Diſh of Lemmons plac'd in a very little room; ſhould a Lemmon or Nut be proportionably magnify'd to what this ſeed of Tyme is, it would make it appear as bigg as a large Hay-reek, and it would be no great wonder to ſee *Homers Iliads*, and *Homer* and all, cramm'd into ſuch a Nut-ſhell. We may perceive even in theſe ſmall Grains, as well as in greater, how curious and carefull Nature is in preſerving the ſeminal principle of Vegetable bodies, in what delicate, ſtrong and moſt convenient Cabinets ſhe

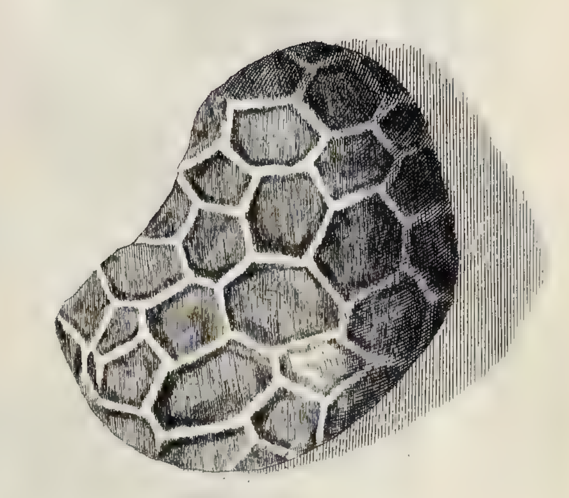
lays them and closes them in a pulp for their safer protection from outward dangers, and for the supply of convenient alimental juice, when the heat of the Sun begins to animate and move these little *automatons* or Engines; as if she would, from the ornaments wherewith she has deckt these Cabinets, hint to us, that in them she has laid up her Jewels and Master-pieces. And this, if we are but diligent in observing, we shall find her method throughout. There is no curiosity in the Elemental kingdom, if I may so call the bodies of Air, Water, Earth, that are comparable in form to those of Minerals; Air and Water having no form at all, unless a potentiality to be form'd into Globules; and the clods and parcels of Earth are all irregular, whereas in Minerals she does begin to *Geometrize*, and practise, as 'twere, the first principles of *Mechanicks*, shaping them of plain regular figures, as triangles, squares, *&c.* and *tetraedrons*, cubes, *&c.* But none of their forms are comparable to the more compounded ones of Vegetables; For here she goes a step further, forming them both of more complicated shapes, and adding also multitudes of curious Mechanick contrivances in their structure; for whereas in Vegetables there was no determinate number of the leaves or branches, nor no exactly certain figure of leaves, or flowers, or seeds, in Animals all those things are exactly defin'd and determin'd; and where-ever there is either an excess or defect of those determinate parts or limbs, there has been some impediment that has spoil'd the principle which was most regular: Here we shall find, not onely most curiously compounded shapes, but most stupendious Mechanisms and contrivances, here the ornaments are in the highest perfection, nothing in all the Vegetable kingdom that is comparable to the deckings of a Peacock; nay, to the curiosity of any feather, as I elsewhere shew; nor to that of the smallest and most despicable Fly. But I must not stay on these speculations, though perhaps it were very well worth while for one that had leisure, to see what Information may be learn'd of the nature, or use, or virtues of bodies, by their several forms and various excellencies and properties. Who knows but *Adam* might from some such contemplation, give names to all creatures? If at least his names had any significancy in them of the creature's nature on which he impos'd it; as many (upon what grounds I know not) have suppos'd: And who knows, but the Creator may, in those characters, have written and engraven many of his most mysterious designs and counsels, and given man a capacity, which, assisted with diligence and industry, may be able to read and understand them. But not to multiply my digression more then I can the time, I will proceed to the next, which is,

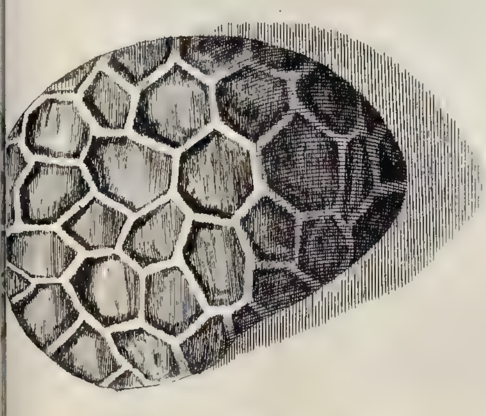
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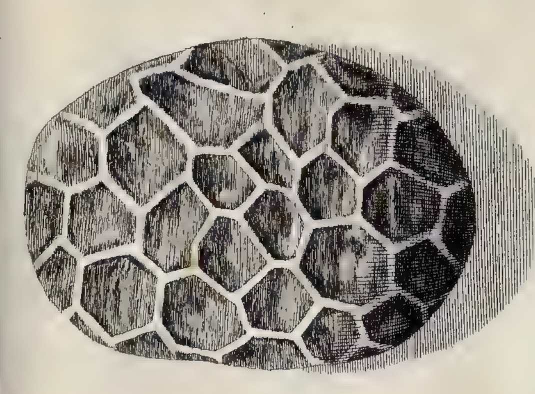
Observ. XXX. *Of the Seeds of* Poppy.

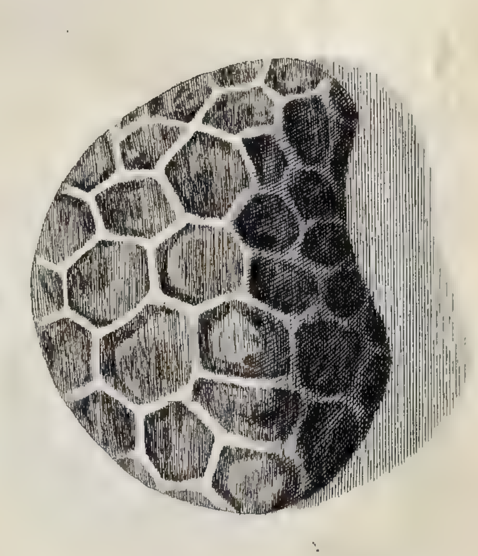
THe small seeds of Poppy, which are described in the 19. *Scheme*, both for their smalness, multiplicity and prettiness, as also for their admirable soporifick quality, deserve to be taken notice of among the other

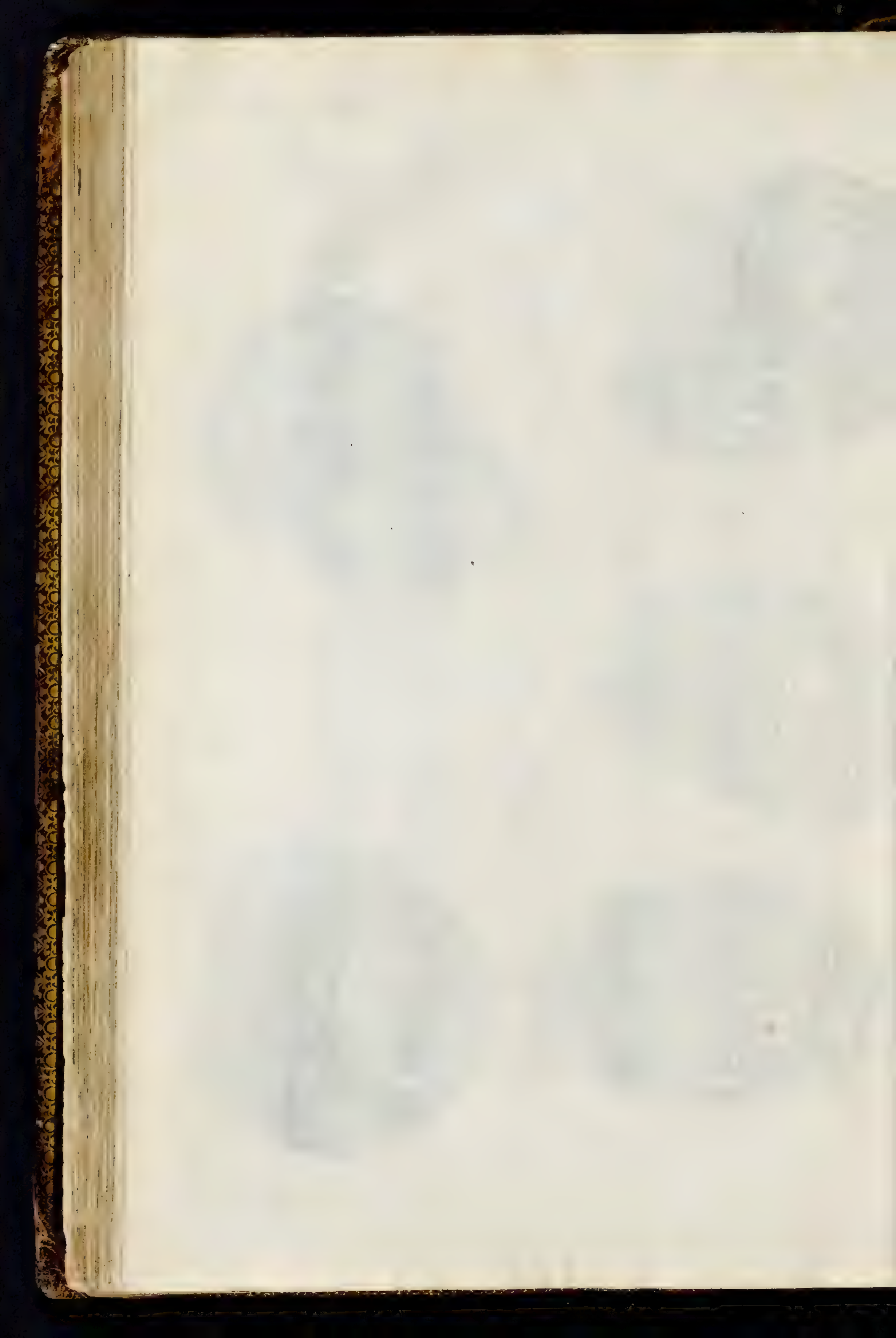


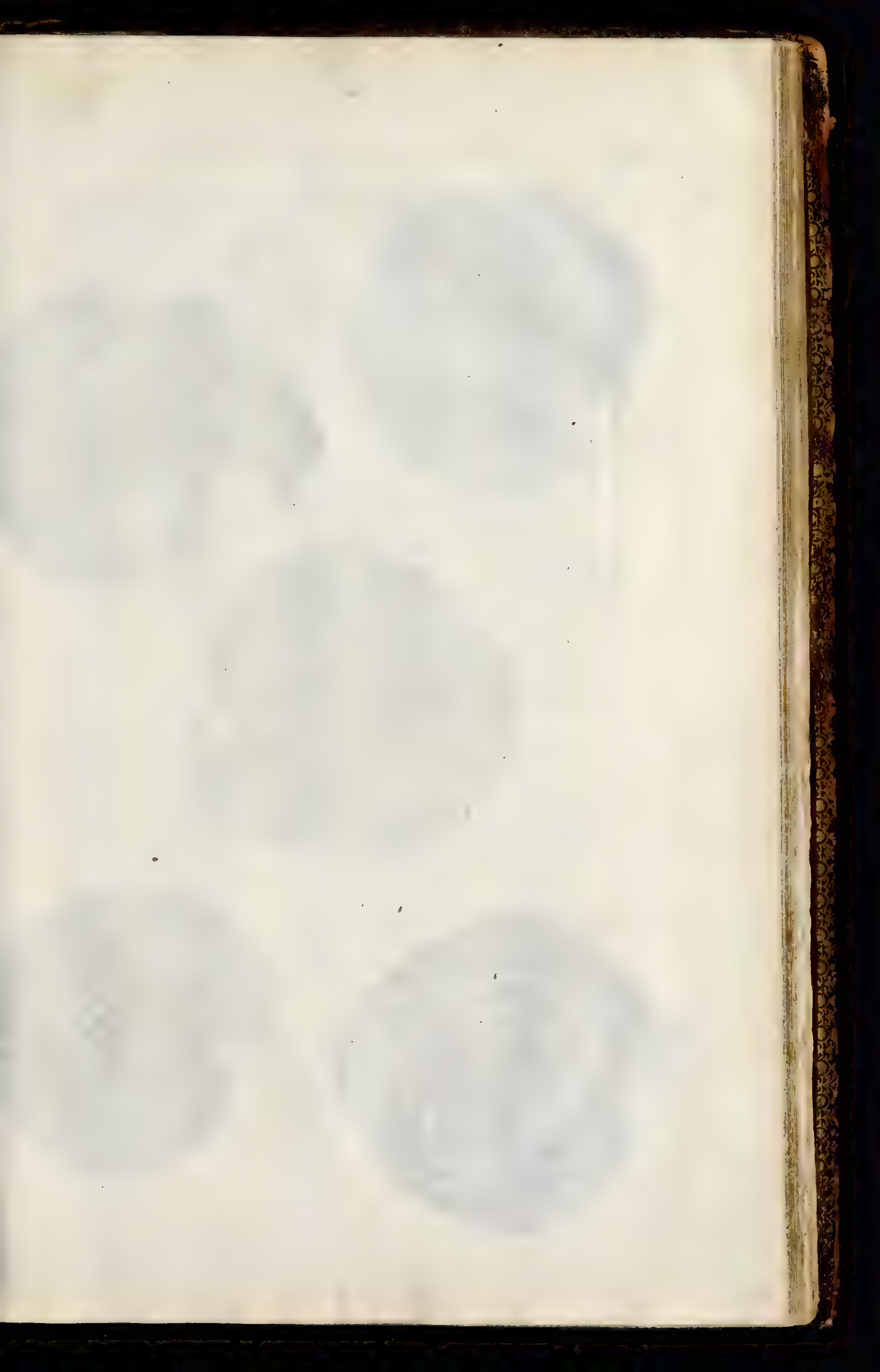












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other *microscopical* seeds of Vegetables: For first, though they grow in a Case or Hive oftentimes bigger then one of these Pictures of the *microscopical* appearance, yet are they for the most part so very little, that they exceed not the bulk of a small Nitt, being not above $\frac{1}{32}$ part of an Inch in Diameter, whereas the Diameter of the Hive of them oftentimes exceeds two Inches, so that it is capable of containing neer two hundred thousand, and so in all likelihood does contain a vast quantity, though perhaps not that number. Next, for their prettiness, they may be compar'd to any *microscopical* seed I have yet seen; for they are of a dark brownish red colour, curiously Honey-comb'd all over with a very pretty variety of Net-work, or a small kind of imbosment of very orderly rais'd ridges, the surface of them looking not unlike the inside of a Beev's stomack. But that which makes it most considerable of all, is, the medicinal virtues of it, which are such as are not afforded us by any Mineral preparation; and that is for the procuring of sleep, a thing as necessary to the well-being of a creature as his meat, and that which refreshes both the voluntary and rational faculties, which, whil'st this affection has seis'd the body, are for the most part unmov'd, and at rest. And, methinks, Nature does seem to hint some very notable virtue or excellency in this Plant from the curiosity it has bestow'd upon it. First, in its flower, it is of the highest scarlet-Dye, which is indeed the prime and chiefest colour, and has been in all Ages of the world most highly esteem'd: Next, it has as much curiosity shew'd also in the husk or case of the seed, as any one Plant I have yet met withall; and thirdly, the very seeds themselves, the *Microscope* discovers to be very curiously shap'd bodies; and lastly, Nature has taken such abundant care for the propagation of it, that one single seed grown into a Plant, is capable of bringing some hundred thousands of seeds.

It were very worthy some able man's enquiry whether the intention of Nature, as to the secundary end of Animal and Vegetable substances might not be found out by some such characters and notable impressions as these, or from divers other circumstances, as the figure, colour, place, time of flourishing, springing and fading, duration, taste, smell, *&c.* For if such there are (as an able *Physician* upon good grounds has given me cause to believe) we might then, insteed of studying Herbals (where so little is deliver'd of the virtues of a Plant, and less of truth) have recourse to the Book of Nature it self, and there find the most natural, usefull, and most effectual and specifick Medicines, of which we have amongst Vegetables, two very noble Instances to incourage such a hope, the one of the *Jesuite powder* for the cure of *intermitting Feavers*, and the other of the juice of *Poppy* for the curing the defect of sleeping.

Obſerv. XXXI. *Of* Purſlane-ſeed.

THe Seeds of *Purſlane* ſeem of very notable ſhapes, appearing through the *Microſcope* ſhap'd ſomewhat like a *nautilus* or *Porcelane* ſhell, as may be ſeen in the XX. *Scheme*, it being a ſmall body, coyl'd round in the manner of a Spiral; at the greater end whereof, which repreſents the mouth or orifice of the Shell, there is left a little white tranſparent ſubſtance, like a ſkin, repreſented by BBBB, which ſeems to have been the place whereunto the ſtem was join'd. The whole ſurface of this *Coclea* or Shell, is cover'd over with abundance of little *prominencies* or buttons very orderly rang'd into Spiral rows, the ſhape of each of which ſeem'd much to reſemble a Wart upon a mans hand. The order, variety, and curioſity in the ſhape of this little ſeed, makes it a very pleaſant object for the *Microſcope*, one of them being cut aſunder with a very ſharp Penknife, diſcover'd this carved Caſket to be of a browniſh red, and ſomewhat tranſparent ſubſtance, and manifeſted the inſide to be fill'd with a whitiſh green ſubſtance or pulp, the Bed wherein the ſeminal principle lies *invelop'd*.

There are multitudes of other ſeeds which in ſhape repreſent or imitate the forms of divers other ſorts of Shells: as the ſeed of *Scurvy-graſs*, very much reſembles the make of a *Concha Venerea*, a kind of Purcelane Shell; others repreſent ſeveral ſorts of larger fruits, ſweat Marjerome and Pot-marjerome repreſent Olives. Carret ſeeds are like a cleft of a Coco-Nut Huſk; others are like Artificial things, as Succory ſeeds are like a Quiver full of Arrows, the ſeeds of *Amaranthus* are of an exceeding lovely ſhape, ſomewhat like an Eye: The ſkin of the black and ſhrivled ſeeds of Onyons and Leeks, are all over knobbed like a Seals ſkin. Sorrel has a pretty black ſhining three-ſquare ſeed, which is picked at both ends with three ridges, that are bent the whole length of it. It were almoſt endleſs to reckon up the ſeveral ſhapes, they are ſo many and ſo various; Leaving them therefore to the curious obſerver, I ſhall proceed to the Obſervations on the parts of Animals.

Obſerv. XXXII. *Of the Figure of ſeveral ſorts of* Hair, *and of the texture of the* ſkin.

VIewing ſome of the Hairs of my Head with a very good *Microſcope*, I took notice of theſe particulars:

1. That they were, for the moſt part, *Cylindrical*, ſome of them were ſomewhat *Priſmatical*, but generally they were veryneer round, ſuch as are repreſented in the ſecond Figure of the 5. *Scheme*, by the *Cylinders* EEE. nor could I find any that had ſharp angules.

2. That

2. That that part which was next the top, was bigger then that which was neerer the root.

3. That they were all along from end to end tranſparent, though not very cleer, the end next the root appearing like a black tranſparent piece of Horn, the end next the top more brown, ſomewhat like tranſparent Horn.

4. That the root of the Hairs were pretty ſmooth, tapering inwards, almoſt like a Parſneb; nor could I find that it had any filaments, or any other veſſels, ſuch as the *fibres* of Plants.

5. That the top when ſplit (which is common in long Hair) appear'd like the end of a ſtick, beaten till it be all flitter'd, there being not onely two ſplinters, but ſometimes half a ſcore and more.

6. That they were all, as farr as I was able to find, ſolid *Cylindrical* bodies, not pervious, like a Cane or Bulruſh; nor could I find that they had any Pith, or diſtinction of Rind, or the like, ſuch as I had obſerv'd in Horſe-hairs, the Briſtles of a Cat, the *Indian* Deer's Hair, *&c.*

Obſervations on ſeveral other ſorts of Hair.

For the Briſles of a Hogg, I found them to be firſt a hard tranſparent horny ſubſtance, without the leaſt appearance of pores or holes in it; and this I try'd with the greateſt care I was able, cutting many of them with a very ſharp Razor, ſo that they appear'd, even in the Glaſs, to have a pretty ſmooth ſurface, but ſomewhat waved by the ſawing to and fro of the Razor, as is viſible in the end of the *Priſmatical* body A of the ſame Figure; and then making trials with cauſing the light to be caſt on them all the various ways I could think of, that was likely to make the pores appear, if there had been any, I was not able to diſcover any.

Next, the Figure of the Briſles was very various, neither perfectly round, nor ſharp edg'd, but *Priſmatical*, with divers ſides, and round angles, as appears in the Figure A. The bending of them in any part where they before appear'd cleer, would all flaw them, and make them look white.

The Muſtacheos of a Cat (part of one of which is repreſented by the ſhort *Cylinder* B of the ſame Figure) ſeem'd to have, all of them that I obſerv'd, a large pith in the middle, like the pith of an Elder, whoſe texture was ſo cloſe, that I was not able to diſcover the leaſt ſign of pores; and thoſe parts which ſeem to be pores, as they appear'd in one poſition to the light, in another I could find a manifeſt reflectiom to be caſt from them.

This I inſtance in, to hint that it is not ſafe to conclude any thing to be poſitively this or that, though it appear never ſo plain and likely when look'd on with a *Microſcope* in one poſture, before the ſame be examin'd by placing it in ſeveral other poſitions.

And this I take to be the reaſon why many have believed and aſſerted the Hairs of a man's head to be hollow, and like ſo many ſmall pipes perforated from end to end.

Now, though I grant that by an *Analogie* one may ſuppoſe them ſo, and

and from the *Polonian* diſeaſe one may believe them ſuch, yet I think we have not the leaſt encouragement to either from the *Microſcope*, much leſs poſitively to aſſert them ſuch. And perhaps the very eſſence of the *Plica Polonica* may be the hairs growing hollow, and of an unnatural conſtitution.

And as for the *Analogie*, though I am apt enough to think that the hairs of ſeveral Animals may be perforated ſomewhat like a Cane, or at leaſt have a kind of pith in them, firſt, becauſe they ſeem as 'twere a kind of Vegetable growing on an Animal, which growing, they ſay, remains a long while after the Animal is dead, and therefore ſhould like other Vegetables have a pith; and ſecondly, becauſe Horns and Feathers, and Porcupine's Quils, and Cats Briſles, and the long hairs of Horſes, which come very neer the nature of a mans hair, ſeem all of them to have a kind of pith, and ſome of them to be porous, yet I think it not (in theſe caſes, where we have ſuch helps for the ſenſe as the *Microſcope* affords) ſafe concluding or building on more then we ſenſibly know, ſince we may, with examining, find that Nature does in the make of the ſame kind of ſubſtance, often vary her method in framing of it: Inſtances enough to confirm this we may find in the Horns of ſeveral creatures: as what a vaſt difference is there between the Horns of an Oxe, and thoſe of ſome ſorts of Staggs as to their ſhape? and even in the hairs of ſeveral creatures, we find a vaſt difference; as the hair of a man's head ſeems, as I ſaid before, long, *Cylindrical* and ſometime a little *Priſmatical*, ſolid or impervious, and very ſmall; the hair of an *Indian* Deer (a part of the middle of which is deſcribed in the third Figure of the fifth *Scheme*, marked with F) is bigger in compaſs through all the middle of it, then the Briſle of an Hogg, but the end of it is ſmaller then the hair of any kind of Animal (as may be ſeen by the Figure G) the whole belly of it, which is about two or three Inches long, looks to the eye like a thread of courſe Canvaſs, that has been newly unwreath'd, it being all wav'd or bended to and fro, much after that manner, but through the *Microſcope*, it appears all perforated from ſide to ſide, and Spongie, like a ſmall kind of ſpongy Coral, which is often found upon the *Engliſh* ſhores; but though I cut it tranſverſly, I could not perceive that it had any pores that ran the long-way of the hair: the long hairs of Horſes C C and D, ſeem *Cylindrical* and ſomewhat pithy; the Briſles of a Cat B, are conical and pithy: the Quils of Porcupines and Hedghoggs, being cut tranſverſly, have a whitiſh pith, in the manner of a Starr, or Spur-rowel: Piggs-hair (A) is ſomewhat *triagonal*, and ſeems to have neither pith nor pore: And other kinds of hair have quite a differing ſtructure and form. And therefore I think it no way agreeable to a true natural Hiſtorian, to pretend to be ſo ſharp-ſighted, as to ſee what a pre-conceiv'd *Hypotheſis* tells them ſhould be there, where another man, though perhaps as ſeeing, but not foreſtall'd, can diſcover no ſuch matter.

But to proceed; I obſerv'd ſeveral kind of hairs that had been Dyed, and found them to be a kind of horny *Cylinder*, being of much about the tranſparency of a pretty cleer piece of Oxe horn; theſe appear'd quite

through-

throughout ting'd with the colours they exhibited. And 'tis likely, that those hairs being boyl'd or steep'd in those very hot ting'd liquors in the Dye-fat, And the substance of the hair being much like that of an Oxes Horn, the penetrant liquor does so far mollifie and soften the substance, that it sinks into the very center of it, and so the ting'd parts come to be mix'd and united with the very body of the hair, and do not (as some have thought) only stick on upon the outward surface. And this, the boiling of Horn will make more probable; for we shall find by that action, that the water will insinuate it self to a pretty depth within the surface of it, especially if this penetrancy of the water be much helped by the Salts that are usually mix'd with the Dying liquors. Now, whereas Silk may be dyed or ting'd into all kind of colours without boiling or dipping into hot liquors, I ghess the reason to be two-fold: First, because the filaments, or small cylinders of Silk, are abundantly smaller and finer, and so have a much less depth to be penetrated then most kind of hairs; and next, because the substance or matter of Silk, is much more like a Glew then the substance of Hair is. And that I have reason to suppose; First, because when it is spun or drawn out of the Worm, it is a perfect glutinous substance, and very easily sticks and cleaves to any adjacent body, as I have several times observed, both in Silk-worms and Spiders. Next, because that I find that water does easily dissolve and mollifie the substance again, which is evident from their manner of ordering those bottoms or pods of the Silk-worm before they are able to unwind them. It is no great wonder therefore, if those Dyes or ting'd liquors do very quickly mollifie and tinge the surfaces of so small and so glutinous a body. And we need not wonder that the colours appear so lovely in the one, and so dull in the other, if we view but the ting'd cylinders of both kinds with a good *Microscope*; for whereas the substance of Hair, at best, is but a dirty duskish white somewhat transparent, the filaments of Silk have a most lovely transparency and cleerness, the difference between those two being not much less then that between a piece of Horn, and a piece of Crystal; the one yielding a bright and vivid reflection from the concave side of the cylinder, that is, from the concave surface of the Air that incompasses the back-part of the cylinder; the other yielding a dull and perturb'd reflection from the several *Heterogeneous* parts that compose it. And this difference will be manifest enough to the eye, if you get a couple of small Cylinders, the smaller of Crystal Glass, the other of Horn, and then varnishing them over very thinly with some transparent colour, which will represent to the naked eye much the same kind of object which is represented to it from the filaments of Silk and Hair by the help of the *Microscope*. Now, since the threads of Silk and Serge are made up of a great number of these filaments, we may henceforth cease to wonder at the difference. From much the same reason proceeds the vivid and lovely colours of Feathers, wherein they very farr exceed the natural as well as Artificial colours of hair, of which I shall say more in its proper place.

The Teguments indeed of creatures are all of them adapted to the peculiar use and convenience of that Animal which they inwrap; and very much

much alſo for the ornament and beauty of it, as will be moſt evident to any one that ſhall attentively conſider the various kinds of cloathings wherewith moſt creatures are by Nature inveſted and cover'd. Thus I have obſerved, that the hair or furr of thoſe Northern white Bears that inhabite the colder Regions, is exceeding thick and warm : the like have I obſerv'd of the hair of a *Greenland* Deer, which being brought alive to *London*, I had the opportunity of viewing ; its hair was ſo exceeding thick, long and ſoft, that I could hardly with my hand, graſp or take hold of his ſkin, and it ſeem'd ſo exceeding warm, as I had never met with any before. And as for the ornamentative uſe of them, it is moſt evident in a multitude of creatures, not onely for colour, as the Leopards, Cats, Rhein Deer, *&c.* but for the ſhape, as in Horſes manes, Cats beards, and ſeveral other of the greater ſort of terreſtrial Animals, but is much more conſpicuous, in the Veſtments of Fiſhes, Birds, Inſects, of which I ſhall by and by give ſome Inſtances.

As for the ſkin, the *Microſcope* diſcovers as great a difference between the texture of thoſe ſeveral kinds of Animals, as it does between their hairs ; but all that I have yet taken notice of, when tann'd or dreſs'd, are of a Spongie nature, and ſeem to be conſtituted of an infinite company of ſmall long *fibres* or hairs, which look not unlike a heap of Tow or Okum ; every of which *fibres* ſeem to have been ſome part of a Muſcle, and probably, whil'ſt the Animal was alive, might have its diſtinct function, and ſerve for the contraction and relaxation of the ſkin, and for the ſtretching and ſhrinking of it this or that way.

And indeed, without ſuch a kind of texture as this, which is very like that of *Spunk*, it would ſeem very ſtrange, how any body ſo ſtrong as the ſkin of an Animal uſually is, and ſo cloſe as it ſeems, whil'ſt the Animal is living, ſhould be able to ſuffer ſo great an extenſion any ways, without at all hurting or dilacerating any part of it. But, ſince we are inform'd by the *Microſcope*, that it conſiſts of a great many ſmall filaments, which are implicated, or intangled one within another, almoſt no otherwiſe then the hairs in a lock of Wool, or the flakes in a heap of Tow, though not altogether ſo looſe ; but the filaments are here and there twiſted, as twere, or interwoven, and here and there they join and unite with one another, ſo as indeed the whole ſkin ſeems to be but one piece, we need not much wonder: And though theſe *fibres* appear not through a *Microſcope*, exactly jointed and contex'd, as in Sponge ; yet, as I formerly hinted, I am apt to think, that could we find ſome way of diſcovering the texture of it, whil'ſt it inveſts the living Animal, or had ſome very eaſie way of ſeparating the pulp or intercurrent juices, ſuch as in all probability fill thoſe *Interſtitia*, without dilacerating, bruſing, or otherwiſe ſpoiling the texture of it (as it ſeems to be very much by the ways of tanning and dreſſing now us'd) we might diſcover a much more curious texture then I have hitherto been able to find ; perhaps, ſomewhat like that of Sponges.

That of *Chamoiſe* Leather is indeed very much like that of *Spunk*, ſave onely that the *filaments* ſeem nothing neer ſo even and round, nor altogether ſo ſmall, nor has it ſo curious joints as *Spunk* has, ſome of which I

have

have lately diſcover'd like thoſe of a Sponge, and perhaps all theſe three bodies may be of the ſame kind of ſubſtance, though two of them indeed are commonly accounted Vegetable (which, whether they be ſo or no, I ſhall not now diſpute) But this ſeems common to all three, that they undergo a tanning or dreſſing, whereby the interſpers'd juices are waſted and waſh'd away before the texture of them can be diſcover'd.

What their way is of dreſſing, or curing Sponges, I confeſs, I cannot learn; but the way of dreſſing *Spunk*, is, by boiling it a good while in a ſtrong *Lixivium*, and then beating it very well; and the manner of dreſſing Leather is ſufficiently known.

It were indeed extremely deſirable, if ſuch a way could be found whereby the *Parenchyma* or fleſh of the Muſcles, and ſeveral other parts of the bod,y might be waſh'd, or waſted clean away, without vitiating the form of the *fibrous* parts or veſſells of it, for hereby the texture of thoſe parts, by the help of a good *Microſcope*, might be moſt accurately found.

But to digreſs no further, we may, from this diſcovery of the *Microſcope*, plainly enough underſtand how the ſkin, though it looks ſo cloſe as it does, comes to give a paſſage to ſo vaſt a quantity of *excrementitious* ſubſtances, as the diligent *Sanctorius* has excellently obſerved it to do, in his *medicina ſtatica*; for it ſeems very probable, from the texture after dreſſing, that there are an infinit of pores that every way pierce it, and that thoſe pores are onely fill'd with ſome kind of juice, or ſome very pulpy ſoft ſubſtance, and thereby the ſteams may almoſt as eaſily find a paſſage through ſuch a fluid *vehicle* as the vaporous bubbles which are generated at the bottom of a Kettle of hot water do find a paſſage through that fluid *medium* into the ambient Air.

Nor is the ſkin of animals only thus pervious, but even thoſe of vegetables alſo ſeem to be the ſame; for otherwiſe I cannot conceive why, if two ſprigs of Roſemary (for Inſtance) be taken as exactly alike in all particulars as can be, and the one be ſet with the bottom in a Glaſs of water, and the other be ſet juſt without the Glaſs, but in the Air onely, though you ſtop the lower end of that in the Air very carefully with Wax, yet ſhall it preſently almoſt wither, whereas the other that ſeems to have a ſupply from the ſubjacent water by its ſmall pipes, or *microſcopical* pores, preſerves its greenneſs for many days, and ſometimes weeks.

Now, this to me, ſeems not likely to proceed from any other cauſe then the *avolation* of the juice through the ſkin; for by the Wax, all thoſe other pores of the ſtem are very firmly and cloſely ſtop'd up. And from the more or leſs porouſneſs of the ſkins or rinds of Vegetables may, perhaps, be ſomewhat of the reaſon given, why they keep longer green, or ſooner wither; for we may obſerve by the bladdering and craking of the leaves of Bays, Holly, Laurel, *&c.* that their ſkins are very cloſe, and do not ſuffer ſo free a paſſage through them of the included juices.

But of this, and of the Experiment of the Roſemary, I ſhall elſewhere more fully conſider, it ſeeming to me an extreme luciferous Experiment, ſuch as ſeems indeed very plainly to prove the *Schematiſm* or ſtructure

of Vegetables altogether *mechanical*, and as neceſſary, that (water and warmth being apply'd to the bottom of the ſprig of a Plant) ſome of it ſhould be carried upwards into the ſtem, and thence diſtributed into the leaves, as that the water of the *Thames* covering the bottom of the Mills at the Bridge foot of *London*, and by the ebbing and flowing of it, paſſing ſtrongly by them, ſhould have ſome part of it convey'd to the Ceſterns above,and thence into ſeveral houſes and Ceſterns up and down the City.

Obſerv. XXXIII. *Of the* Scales *of a* Soal, *and other Fiſhes.*

HAving hinted ſomewhat of the ſkin and covering of terreſtrial Animals, I ſhall next add an Obſervation I made on the ſkin and Scales of a *Soal*, a ſmall Fiſh, commonly enough known; and here in Fiſhes, as well as other Animals, Nature follows its uſual method, framing all parts ſo, as that they are both uſefull and ornamental in all its compoſures, mingling *utile* and *dulce* together; and both theſe deſigns it ſeems to follow,though our unaſſiſted ſenſes are not able to peceive them : This is not onely manifeſt in the covering of this Fiſh only, but in multitudes of others,which it would be too long to enumerate,witneſs particularly that ſmall Sand Shell, which I mention'd in the XI. Obſervation, and infinite other ſmall Shells and Scales, divers of which I have view'd. This ſkin I view'd, was flead from a prettylarge *Soal*, and then expanded and dry'd, the inſide of it, when dry, to the naked eye, look'd very like a piece of Canvaſs,but the *Microſcope* diſcover'd that texture to be nothing elſe,but the inner ends of thoſe curious Scolop'd Scales I, I, I, in the ſecond *Figure* of the XI. *Scheme*, namely, the part of GGGG (of the larger repreſentation of a ſingle Scale, in the firſt *Figure* of the ſame *Scheme*) which on the back ſide, through an ordinary ſingle Magnifying Glaſs, look'd not unlike the Tyles on an houſe.

The outſide of it, to the naked eye, exhibited nothing more of ornament, ſave the uſual order of ranging the Scales into a *triagonal* form, onely the edges ſeem'd a little to ſhine, the finger being rubb'd from the tail-wards towards the head, the Scales ſeem'd to ſtay and raze it; But through an ordinary Magnifying glaſs, it exhibited a moſt curiouſly carved and adorned ſurface, ſuch as is viſible in the ſecond *Figure*, each of thoſe (formerly almoſt imperceptible) Scales appearing much of the ſhape I, I, I, that is, they were round, and protuberant, and ſomewhat ſhap'd like a Scolop, the whole Scale being creas'd with curiouſly wav'd and indented ridges,with proportionable furrows between;each of which was terminated with a very ſharp tranſparent bony ſubſtance,which,like ſo many ſmall Turnpikes, ſeem'd to arm the edges.

The back part KKK was the ſkin into which each of theſe Scales were very deeply fix'd, in the curious regular order, viſible in the ſecond *Figure.*

Schem. XXI



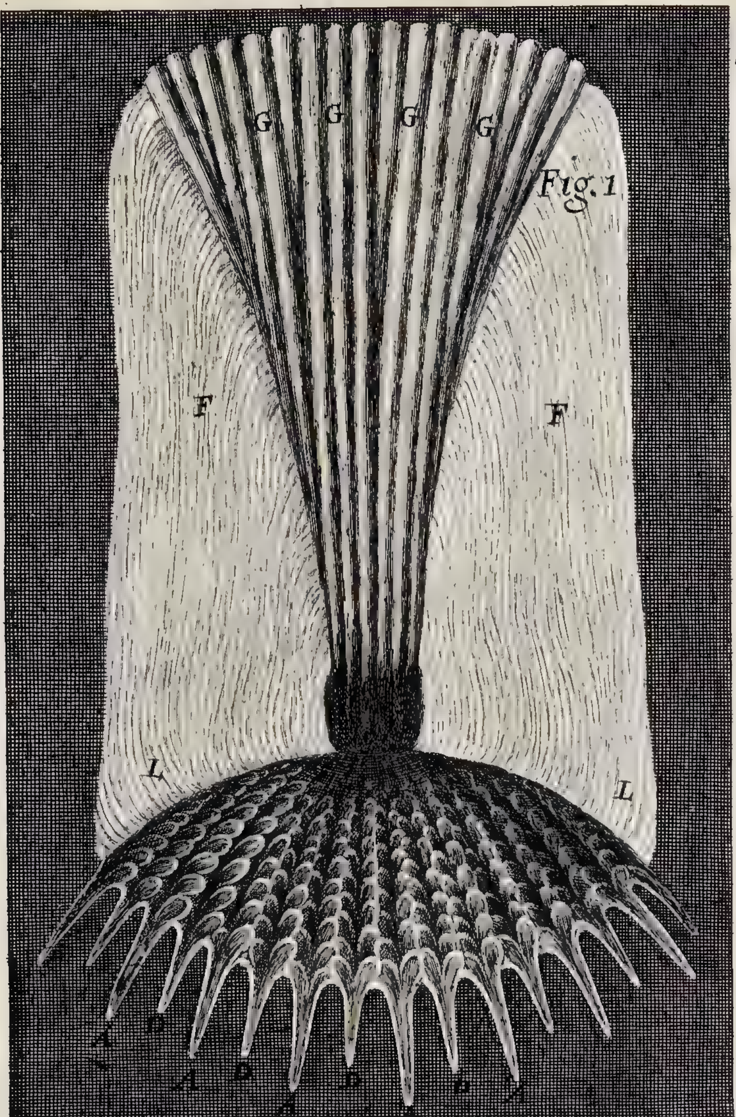
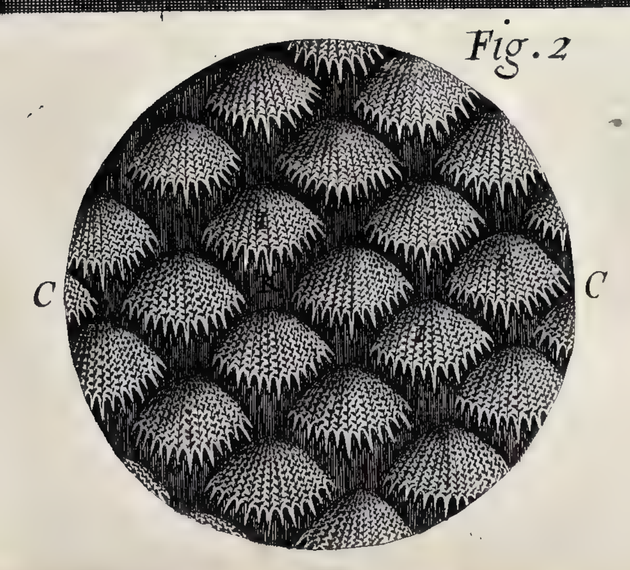
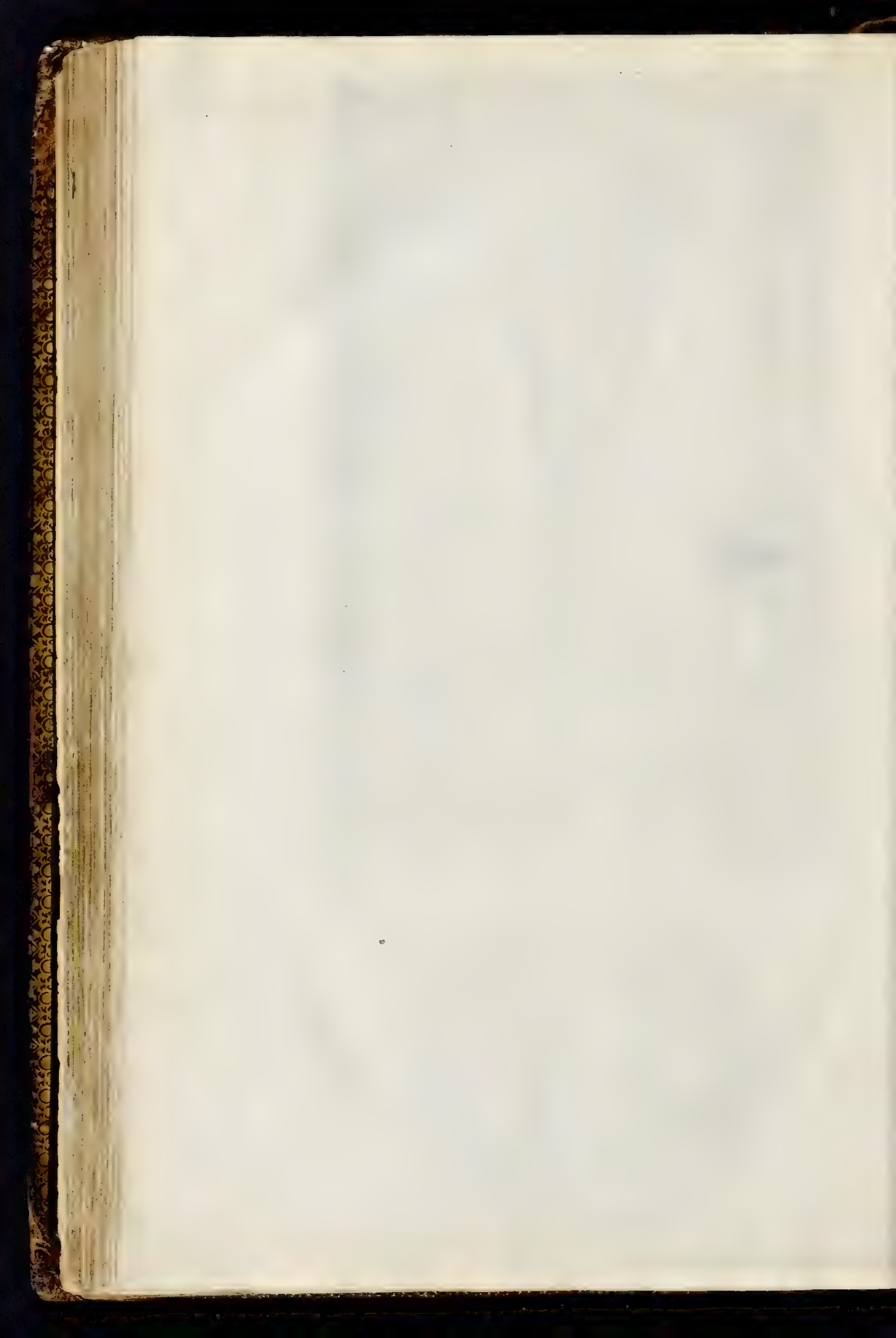
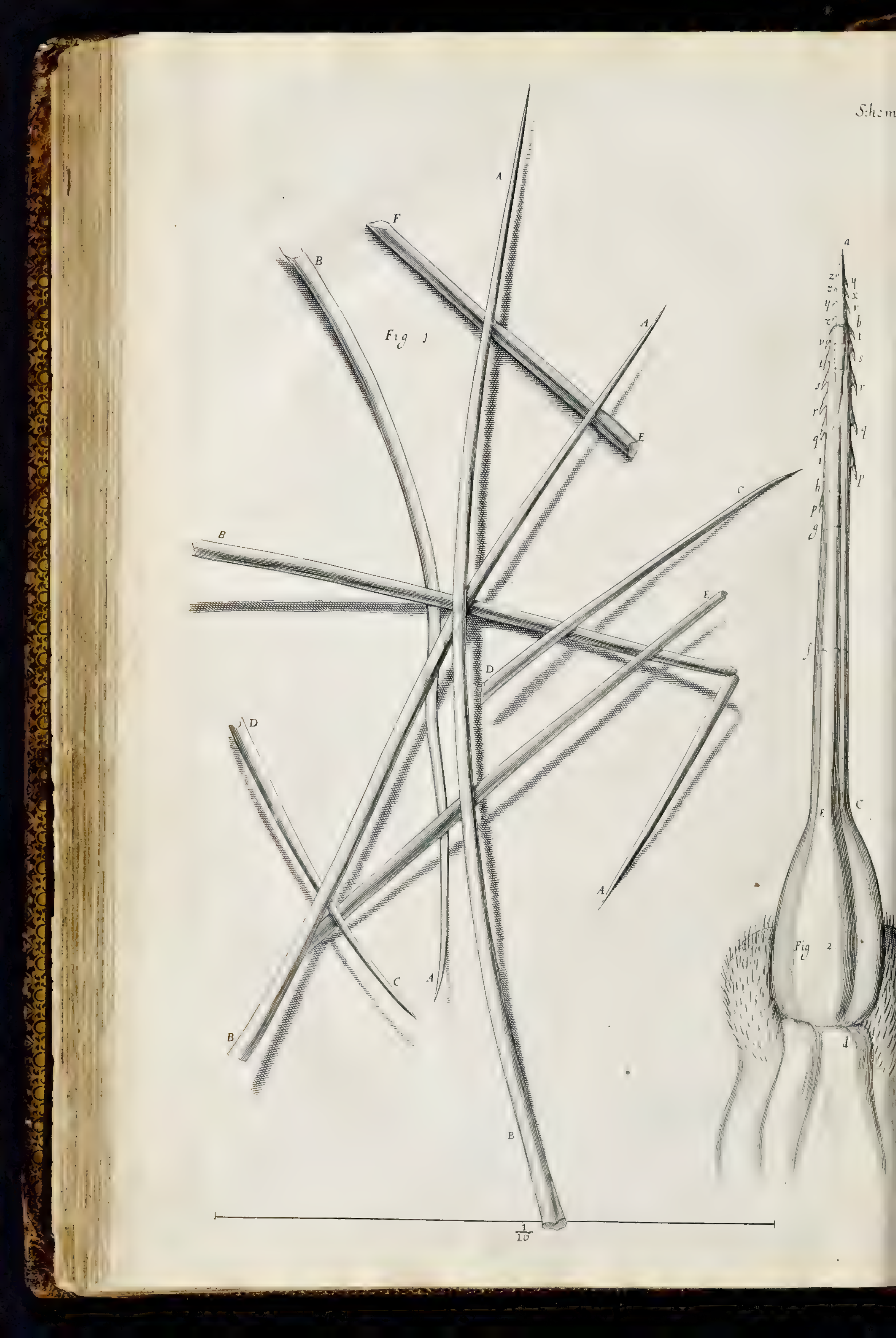


Fig. 2









Schem
Fig 1
Fig 2

Figure. The length and ſhape of the part of the Scale which was buried by the ſkin,is evidenced by the firſt *Figure*; which is the repreſentation of one of them pluck'd out and view'd through a good *Microſcope*, namely, the part L F G G F L, wherein is alſo more plainly to be ſeen,the manner of carving of the ſcolopt part of every particular Scale,how each ridge or barr E E E is alternately hollowed or engraven, and how every gutter between them is terminated with very tranſparent and hard pointed ſpikes, and how every other of theſe, as A A A A, are much longer then the interjacent ones, D D D.

The texture or form alſo of the hidden part appears, namely, the middle part, G G G, ſeems to conſiſt of a great number of ſmall quills or pipes, by which, perhaps, the whole may be nouriſhed; and the ſide parts F F conſiſt of a more fibrous texture, though indeed the whole Scale ſeem'd to be of a very tough griſly ſubſtance,like the larger Scales of other Fiſhes.

The Scales of the ſkin of a Dog-fiſh (which is us'd by ſuch as work in Wood,for the ſmoothing of their work,and conſiſts plainly enough to the naked eye,of a great number of ſmall horny points)through the *Microſcope* appear'd each of them curiouſly ridg'd, and very neatly carved; and indeed, you can hardly look on the ſcales of any Fiſh, but you may diſcover abundance of curioſity and beautifying; and not only in theſe Fiſhes,but in the ſhells and cruſts or armour of moſt ſorts of *Marine* Animals ſo inveſted.

Obſerv. XXXIV. *Of the Sting of a* Bee.

THe Sting of a *Bee*, delineated in the ſecond Figure of the XVI. *Scheme*, ſeems to be a weapon of offence, and is as great an Inſtance, that Nature did realy intend revenge as any, and that firſt, becauſe there ſeems to be no other uſe of it. Secondly, by reaſon of its admirable ſhape, ſeeming to be purpoſely ſhap'd for that very end. Thirdly,from the virulency of the liquor it ejects, and the ſad effects and ſymptoms that follow it.

But whatever be the uſe of it,certain it is,that the ſtructure of it is very admirable; what it appears to the naked eye, I need not deſcribe, the thing being known almoſt to every one,but it appears through the *Microſcope*, to conſiſt of two parts, the one a ſheath, without a chape or top, ſhap'd almoſt like the Holſter of a Piſtol, beginning at *d*, and ending at *b*,this ſheath I could moſt plainly perceive to be hollow, and to contain in it,both a Sword or Dart, and the poiſonous liquor that cauſes the pain. The ſheath or caſe ſeem'd to have ſeveral joints or ſettings together, marked by *f g h i k l m n o*, it was arm'd moreover neer the top, with ſeveral crooks or forks (*p q r ſ t*) on one ſide, and (*p q r ſ t u*) on the other, each of which ſeem'd like ſo many Thorns growing on a briar, or rather like ſo many Cat's Claws; for the crooks themſelves ſeem'd to be little ſharp tranſparent points or claws, growing out of little *protuberancies* on

the ſide of the ſheath, which, by obſerving the Figure diligently, is eaſie enough to be perceiv'd; and from ſeveral particulars, I ſuppoſe the Animal has a power of diſplaying them, and ſhutting them in again as it pleaſes, as a Cat does its claws, or as an Adder or Viper can its teeth or fangs.

The other part of the Sting was the Sword, as I may ſo call it, which is ſheath'd, as it were, in it, the top of which *a b* appears quite through at the ſmaller end, juſt as if the chape of the ſheath of a Sword were loſt, and the end of it appear'd beyond the Scabbard; the end of this Dart (*a*) was very ſharp, and it was arm'd likewiſe with the like Tenterhooks or claws with thoſe of the ſheath, ſuch as (*v x y, x y z z*) theſe crooks, I am very apt to think, can be clos'd up alſo, or laid flat to the ſides of the Sword when it is drawn into the Scabbard, as I have ſeveral times obſerv'd it to be, and can be ſpred again or extended when ever the Animal pleaſes.

The conſideration of which very pretty ſtructure, has hinted to me, that certainly the uſe of theſe claws ſeems to be very conſiderable, as to the main end of this Inſtrument, for the drawing in, and holding the ſting in the fleſh; for the point being very ſharp, the top of the Sting or Dagger (*a b*) is very eaſily thruſt into an Animal's body, which being once entred, the Bee, by endeavouring to pull it into the ſheath, draws (by reaſon of the crooks (*v x y*) and (*x y z z*) which lay hold of the ſkin on either ſide) the top of the ſheath (*t ſ r v*) into the ſkin after it, and the crooks *t, s,* and *r, v,* being entred, when the Bee endeavours to thruſt out the top of the ſting out of the ſheath again, they lay hold of the ſkin on either ſide, and ſo not onely keep the ſheath from ſliding back, but helps the top inwards, and thus, by an alternate and ſucceſſive retracting and emitting of the Sting in and out of the ſheath, the little enraged creature by degrees makes his revengfull weapon pierce the tougheſt and thickeſt Hides of his enemies, in ſo much that ſome few of theſe ſtout and reſolute ſoldiers with theſe little engines, do often put to flight a huge maſty Bear, one of their deadly enemies, and thereby ſhew the world how much more conſiderable in Warr a few ſkilfull Engineers and reſolute ſoldiers politickly order'd, that know how to manage ſuch engines, are, then a vaſt unweildy rude force, that confides in, and acts onely by, its ſtrength. But (to proceed) that he thus gets in his Sting into the ſkin, I conjecture, becauſe, when I have obſerv'd this creature living, I have found it to move the Sting thus, to and fro, and thereby alſo, perhaps, does, as 'twere, pump or force out the poiſonous liquor, and make it hang at the end of the ſheath about *b* in a drop. The crooks, I ſuppoſe alſo to be the cauſe why theſe angry creatures, haſtily removing themſelves from their revenge, do often leave theſe weapons behind them, ſheath'd, as 'twere, in the fleſh, and, by that means, cauſe the painfull ſymptoms to be greater, and more laſting, which are very probably caus'd, partly by the piercing and tearing of the ſkin by the Sting, but chiefly by the corroſive and poiſonous liquor that is by this Syringe-pipe convey'd among the ſenſitive parts thereof and thereby more eaſily gnaws

and

and corrodes those tender *fibres:* As I have shewed in the description of a Nettle and of Cowhage.

Observ. XXXV. *Of the contexture and shape of the particles of* Feathers.

EXamining several sorts of *Feathers*, I took notice of these particulars in all sorts of wing-Feathers, especially in those which serv'd for the beating of the air in the action of flying.

That the outward surface of the Quill and Stem was of a very hard, stiff, and horny substance, which is obvious enough, and that the part above the Quill was fill'd with a very white and light pith, and, with the *Microscope*, I found this pith to be nothing else, but a kind of natural *congeries* of small bubbles, the films of which seem to be of the same substance with that of the Quill, that is, of a stiff transparent horny substance.

Which particular seems to me, very worthy a more serious consideration; For here we may observe Nature, as 'twere, put to its shifts, to make a substance, which shall be both light enough, and very stiff and strong, without varying from its own establish'd principles, which we may observe to be such, that very strong bodies are for the most part very heavie also, a strength of the parts usually requiring a density, and a density a gravity; and therefore should Nature have made a body so broad and so strong as a Feather, almost, any other way then what it has taken, the gravity of it must necessarily have many times exceeded this; for this pith seems to be like so many stops or cross pieces in a long optical tube, which do very much contribute to the strength of the whole, the pores of which were such, as that they seem'd not to have any communication with one another, as I have elsewhere hinted.

But the Mechanism of Nature is usually so excellent, that one and the same substance is adapted to serve for many ends. For the chief use of this, indeed, seems to be for the supply of nourishment to the downy or feathery part of the stem; for 'tis obvious enough in all sorts of Feathers, that 'tis plac'd just under the roots of the branches that grow out of either side of the quill or stalk, and is exactly shap'd according to the ranking of those branches, coming no lower into the quill, then just the beginning of the downy branches, and growing onely on the under side of of the quill where those branches do so. Now, in a ripe Feather (as one may call it) it seems difficult to conceive how the *Succus nutritius* should be convey'd to this pith; for it cannot, I think, be well imagin'd to pass through the substance of the quill, since, having examin'd it with the greatest diligence I was able, I could not find the least appearance of pores; but he that shall well examine an unripe or pinn'd Feather, will plainly enough perceive the Vessel for the conveyance of it to be the thin filmy pith (as tis call'd) which passes through the middle of the quill.

As for the make and contexture of the Down it self, it is indeed very

rare

rare and admirable, and ſuch as I can hardly believe,that the like is to be diſcover'd in any other body in the world; for there is hardly a large Feather in the wing of a Bird,but contains neer a million of diſtinct parts, and every one of them ſhap'd in a moſt regular & admirable form,adapted to a particular Deſign : For examining a middle ciz'd Gooſe-quill, I eaſily enough found with my naked eye,that the main ſtem of it contain'd about 300. longer and more Downy branchings upon one ſide, and as many on the other of more ſtiff but ſomewhat ſhorter branchings. Many of theſe long and downy branchings, examining with an ordinary *Microſcope*, I found divers of them to contain neer 1200. ſmall leaves (as I may call them, ſuch as E F of the firſt Figure of the 23. *Scheme*) and as many ſtalks ; on the other ſide, ſuch as I K of the ſame Figure, each of the leaves or branchings, E F, ſeem'd to be divided into about ſixteen or eighteen ſmall joints, as may be ſeen plainly enough in the Figure, out of moſt of which there ſeem to grow ſmall long *fibres*, ſuch as are expreſs'd in the Figure, each of them very proportionably ſhap'd according to its poſition, or plac'd on the ſtalk E F ; thoſe on the under ſide of it, namely, 1, 2, 3, 4, 5, 6, 7, 8, 9, *&c.* being much longer then thoſe directly oppoſite to them on the upper ; and divers of them, ſuch as 2,3,4,5,6,7,8,9, *&c.* were terminated with ſmall crooks, much reſembling thoſe ſmall crooks,which are viſible enough to the naked eye, in the ſeed-buttons of Bur-docks. The ſtalks likewiſe, I K on the other ſide, ſeem'd divided into neer as many ſmall knotted joints,but without any appearance of ſtrings or crooks,each of them about the middle K,ſeem'd divided into two parts by a kind of fork, one ſide of which, namely, K L, was extended neer the length of K I, the other, M, was very ſhort.

The tranſverſe Sections of the ſtems of theſe branchings, manifeſted the ſhape or figure of it to be much like I N O E, which conſiſted of a horny ſkin or covering, and a white ſeemingly frothy pith, much like the make of the main ſtem of a Feather.

The uſe of this ſtrange kind of form,is indeed more admirable then all the reſt, and ſuch as deſerves to be much more ſeriouſly examin'd and conſider'd, then I have hitherto found time or ability to do ; for certainly, it may very much inſtruct us in the nature of the Air, eſpecially as to ſome properties of it.

The ſtems of the Downy branches I N O E, being rang'd in the order viſible enough to the naked eye, at the diſtance of I F, or ſomewhat more, the *collateral* ſtalks and leaves (if I may ſo call thoſe bodies I newly deſcribed) are ſo rang'd, that the leaves or hairy ſtalks of the one ſide lie at top, or are incumbent on the ſtalks of the other, and croſs each other, much after the manner expreſs'd in the ſecond Figure of the 23. *Scheme*, by which means every of thoſe little hooked *fibres* of the leaved ſtalk get between the naked ſtalks, and the ſtalks being full of knots, and a prety way diſ-join' ſo as that the *fibres* can eaſily get between them, the two parts are ſo cloſely and admirably woven together, that it is able to impede,for the greateſt part, the tranſcurſion of the Air ; and though they are ſo exceeding ſmall, as that the thickneſs of one of

theſe


Schem: XXII.
Fig: 1.
Fig. 2
Fig: 3.
Fig. 4.
Fig. 5.
1/32 of an inch

theſe ſtalks amounts not to a 500. part of an Inch, yet do they compoſe ſo ſtrong a texture, as, notwithſtanding the exceeding quick and violent beating of them againſt the Air, by the ſtrength of the Birds wing, they firmly hold together. And it argues an admirable providence of Nature in the contrivance and fabrick of them; for their texture is ſuch, that though by any external injury the parts of them are violently diſ-joyn'd, ſo as that the leaves and ſtalks touch not one another, and conſequently ſeveral of theſe rents would impede the Bird's flying; yet, for the moſt part, of themſelves they readily re-join and re-contex themſelves, and are eaſily by the Birds ſtroking the Feather, or drawing it through its Bill, all of them ſettled and woven into their former and natural poſture; for there are ſuch an infinite company of thoſe ſmall *fibres* in the under ſide of the leaves, and moſt of them have ſuch little crooks at their ends, that they readily catch and hold the ſtalks they touch.

From which ſtrange contexture, it ſeems rational to ſuppoſe that there is a certain kind of meſh or hole ſo ſmall, that the Air will not very eaſily paſs through it, as I hinted alſo in the ſixth Obſervation about ſmall Glaſs Canes, for otherwiſe it ſeems probable, that Nature would have drawn over ſome kind of thin film which ſhould have covered all thoſe almoſt ſquare meſhes or holes, there ſeeming through the *Microſcope* to be more then half of the ſurface of the Feather which is open and viſibly pervious; which conjecture will yet ſeem more probable from the texture of the bruſhie wings of the *Tinea argentea*, or white Feather wing'd moth, which I ſhall anone deſcribe. But Nature, that knows beſt its own laws, and the ſeveral properties of bodies, knows alſo beſt how to adapt and fit them to her deſigned ends, and whoſo would know thoſe properties, muſt endeavour to trace Nature in its working, and to ſee what courſe ſhe obſerves. And this I ſuppoſe will be no inconſiderable advantage which the *Schematiſms* and Structures of Animate bodies will afford the diligent enquirer, namely, moſt ſure and excellent inſtructions, both as to the practical part of *Mechanicks* and to the *Theory* and knowledge of the nature of the bodies and motions.

Obſerv. XXXVI. *Of* Peacoks, Ducks, *and other* Feathers *of changeable colours.*

THe parts of the Feathers of this glorious Bird appear, through the *Microſcope*, no leſs gaudy then do the whole Feathers; for, as to the naked eye 'tis evident that the ſtem or quill of each Feather in the tail ſends out multitudes of *Lateral* branches, ſuch as A B in the third Figure of the 23. *Scheme* repreſents a ſmall part of about $\frac{1}{32}$ part of an Inch long, and each of the *lateral* branches emit multitudes of little ſprigs, threads or hairs on either ſide of them, ſuch as C D, C D, C D, ſo each of thoſe threads in the *Microſcope* appears a large long body, conſiſting of a multi-

tude

tude of bright reflecting parts, whofe Figure 'tis no eafie matter to determine, as he that examines it fhall find; for every new pofition of it to the light makes it perfectly feem of another form and fhape,and nothing what it appear'd a little before; nay, it appear'd very differing ofttimes from fo feemingly inconfiderable a circumftance, that the interpofing of ones hand between the light and it,makes a very great change, and the opening or fhutting a Cafement and the like, very much diverfifies the appearance. And though, by examining the form of it very many ways, which would be tedious here to enumerate, I fuppofe I have difcover'd the true Figure of it, yet oftentimes, upon looking on it in another pofture, I have almoft thought my former obfervations deficient, though indeed, upon further examination, I have found even thofe alfo to confirm them.

Thefe threads therefore I find to be a *congeries* of fmall *Laminæ* or plates, as *e e e e e*, &c. each of them fhap'd much like this of *a b c d*, in the fourth *Figure*, the part *a c* being a ridge, prominency, or ftem, and *b* and *d* the corners of two fmall thin Plates that grow unto the fmall ftalk in the middle, fo that they make a kind of little feather; each of thefe Plates lie one clofe to another,almoft like a company of floping ridge or gutter Tyles; they grow on each fide of the ftalk oppofite to one another, by two and two, from top to bottom, in the manner exprefs'd in the fifth Figure, the tops of the lower covering the roots of the next above them; the under fide of each of thefe laminated bodies, is of a very dark and opacous fubftance, and fuffers very few Rays to be trajected, but reflects them all toward that fide from whence they come, much like the foil of a Looking-glafs; but their upper fides feem to me to confift of a multitude of thin plated bodies, which are exceeding thin, and lie very clofe together, and thereby, like mother of Pearl fhells, do not onely reflect a very brifk light, but tinge that light in a moft curious manner; and by means of various pofitions, in refpect of the light, they reflect back now one colour, and then another, and thofe moft vividly.

Now, that thefe colours are onely *fantaftical* ones, that is, fuch as arife immediately from the refractions of the light, I found by this, that water wetting thefe colour'd parts,deftroy'd their colours,which feem'd to proceed from the alteration of the reflection and refraction. Now, though I was not able to fee thofe hairs at all tranfparent by a common light, yet by looking on them againft the Sun, I found them to be ting'd with a darkifh red colour, nothing a-kin to the curious and lovely greens and blues they exhibited.

What the reafon of colour feems to be in fuch thin plated bodies, I have elfewhere fhewn. But how water caft upon thofe threads deftroys their colours, I fuppofe to be perform'd thus; The water falling upon thefe plated bodies from its having a greater congruity to Feathers then the Air,infinuates it felf between thofe Plates,and fo extrudes the ftrong reflecting Air, whence both thefe parts grow more tranfparent,as the *Microfcope* informs, and colourlefs alfo, at beft retaining a very faint and

dull colour. But this wet being waſted away by the continual evaporations and ſteams that paſs through them from the Peacock, whil'ſt that Bird is yet alive, the colours again appear in their former luſter, the *interſtitia* of theſe Plates being fill'd with the ſtrongly reflecting Air.

The beauteous and vivid colours of the Feathers of this Bird, being found to proceed from the curious and exceeding ſmalneſs and fineneſs of the reflecting parts, we have here the reaſon given us of all thoſe gauderies in the apparel of other Birds alſo, and how they come to exceed the colours of all other kinds of Animals, beſides Inſects; for ſince (as we here, and elſewhere alſo ſhew) the vividneſs of a colour, depends upon the fineneſs and tranſparency of the reflecting and refracting parts; and ſince our *Microſcope* diſcovers to us, that the component parts of feathers are ſuch, and that the hairs of Animals are otherwiſe; and ſince we find alſo by the Experiment of that Noble and moſt Excellent Perſon I formerly named; that the difference between Silk and Flax, as to its colour, is nothing elſe (for Flax reduc'd to a very great fineneſs of parts, both white and colour'd, appears as white and as vivid as any Silk, but loſes that brightneſs and its Silken aſpect as ſoon as it is twiſted into thread, by reaſon that the component parts, though very ſmall and fine, are yet pliable flakes, and not cylinders, and thence, by twiſting, become united into one opacous body, whereas the threads of Silk and Feathers retain their luſtre, by preſerving their cylindrical form intire without mixing; ſo that each reflected and refracted beam that compoſes the gloſs of Silk, preſerves its own property of modulating the light intire); And ſince we find the ſame confirm'd by many other Experiments elſewhere mentioned, I think we may ſafely conclude this for an Axiome, that whereſoever we meet with tranſparent bodies, ſpun out into very fine parts, either cleer, or any ways ting'd, the colours reſulting from ſuch a *compoſition* muſt neceſſarily be very glorious, vivid, and cleer, like thoſe of Silk and Feathers. This may perhaps hint ſome uſefull way of making other bodies, beſides Silk, be ſuſceptible of bright tinctures, but of this onely by the by.

The changeable colour'd Feathers alſo of Ducks, and ſeveral other Birds, I have found by examination with my *Microſcope*, to proceed from much the ſame cauſes and textures.

Obſerv. XXXVII. *Of the Feet of* Flies, *and ſeveral other* Inſects.

THe foot of a Fly (delineated in the firſt *Figure* of the 23. *Scheme*, which repreſents three joints, the two Tallons, and the two Pattens in a flat poſture; and in the ſecond *Figure* of the ſame *Scheme*, which repreſents onely one joint, the Tallons and Pattens in another poſture) is of a moſt admirable and curious contrivance, for by this the Flies are inabled to walk againſt the ſides of Glaſs, perpendicularly upwards, and to

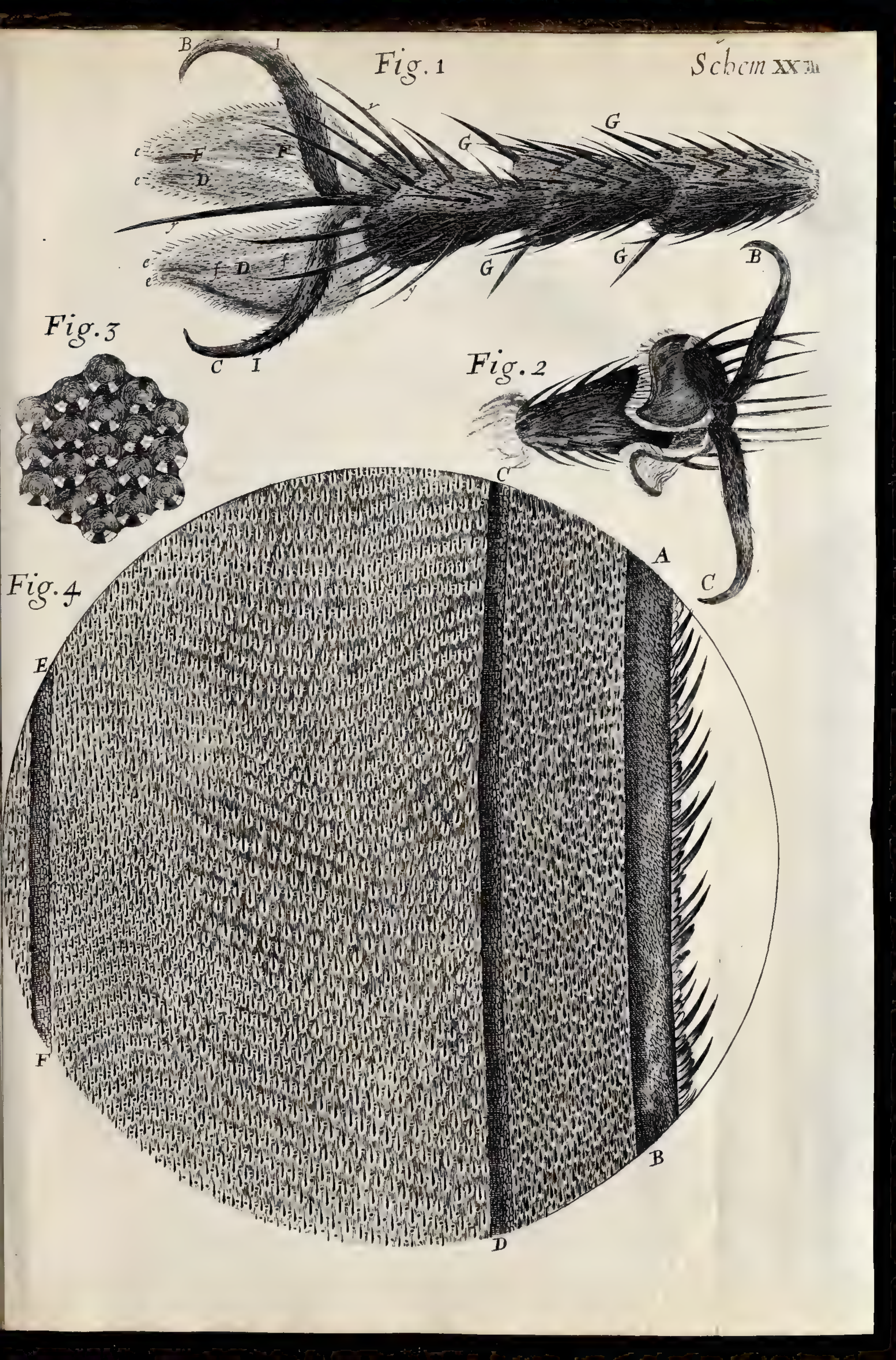
contain themſelves in that poſture as long as they pleaſe; nay, to walk and ſuſpend themſelves againſt the under ſurface of many bodies, as the ceiling of a room, or the like, and this with as great a ſeeming facility and firmneſs, as if they were a kind of *Antipodes*, and had a *tendency* upwards, as we are ſure they have the contrary, which they alſo evidently diſcover, in that they cannot make themſelves ſo light, as to ſtick or ſuſpend themſelves on the under ſurface of a Glaſs well poliſh'd and cleans'd; their ſuſpenſion therefore is wholly to be aſcrib'd to ſome Mechanical contrivance in their feet; which, what it is, we ſhall in brief explain, by ſhewing, that its Mechaniſm conſiſts principally in two parts, that is, firſt its two Claws, or Tallons, and ſecondly, two Palms, Pattens, or Soles.

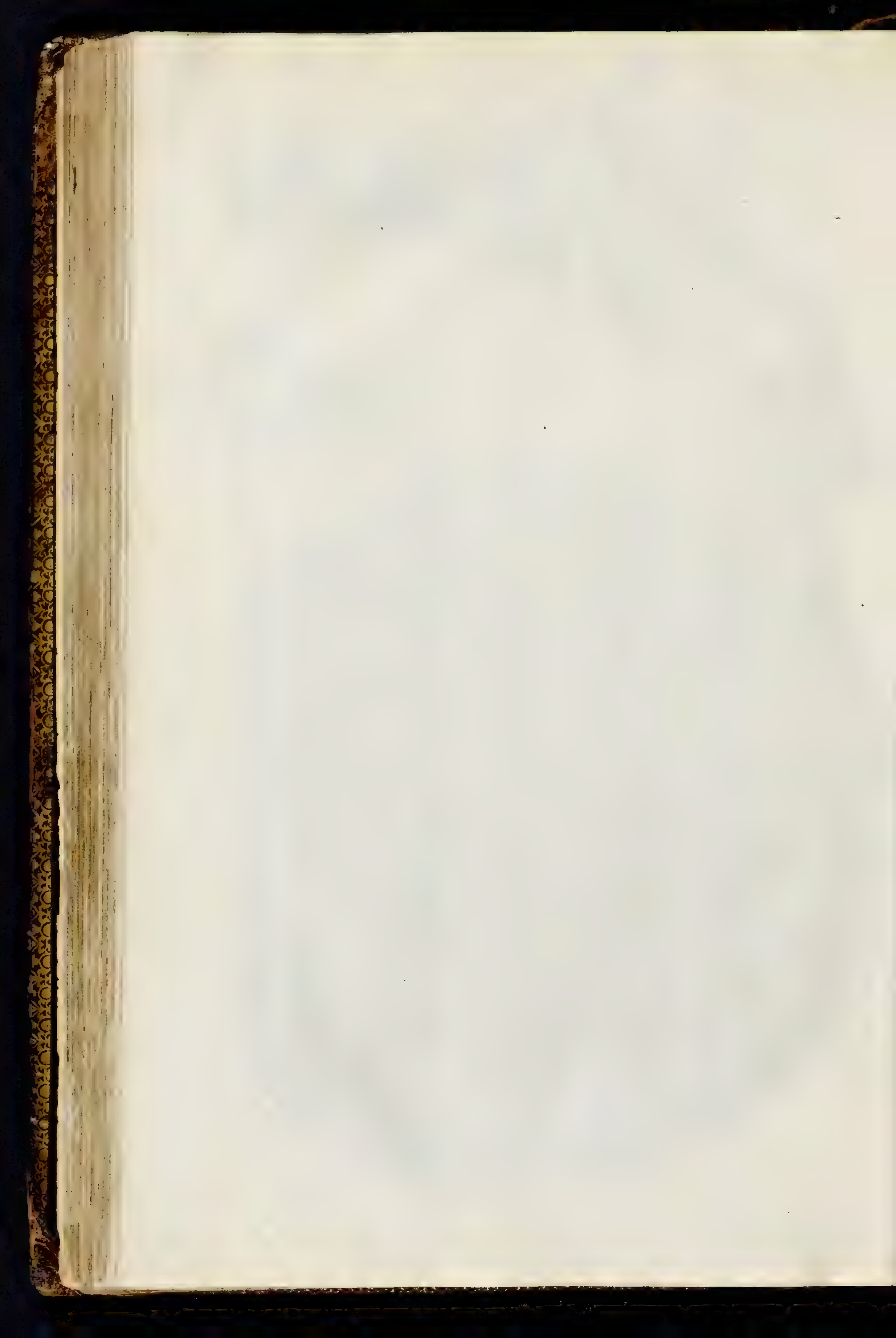
The two Tallons are very large, in proportion to the foot, and handſomly ſhap'd in the manner deſcrib'd in the *Figures*, by A B, and A C, the bigger part of them from A to *d d*, is all hairy, or briſled, but toward the top, at C and B ſmooth, the tops or points, which ſeem very ſharp turning downwards and inwards, are each of them mov'd on a joint at A, by which the Fly is able to open or ſhut them at pleaſure, ſo that the points B and C being entered in any pores, and the Fly endeavouring to ſhut them, the Claws not onely draw one againſt another, and ſo faſten each other, but they draw the whole foot, G G A D D forward, ſo that on a ſoft footing, the tenters or points G G G G, (whereof a Fly has about ten in each foot, to wit, two in every joint) run into the pores, if they find any, or at leaſt make their way; and this is ſenſible to the naked eye, in the feet of a *Chafer*, which, if he be ſuffer'd to creep over the hand, or any other part of the ſkin of ones body, does make his ſteps as ſenſible to the touch as the ſight.

But this contrivance, as it often fails the *Chafer*, when he walks on hard and cloſe bodies, ſo would it alſo our Fly, though he be a much leſſer, and nimbler creature, and therefore Nature has furniſh'd his foot with another *additament* much more curious and admirable, and that is, with a couple of Palms, Pattens or Soles D D, the ſtructure of which is this:

From the bottom or under part of the laſt joint of his foot, K, ariſe two ſmall thin plated horny ſubſtances, each conſiſting of two flat pieces, D D, which ſeem to be flexible, like the covers of a Book, about F F, by which means, the plains of the two ſides E E, do not always lie in the ſame plain, but may be ſometimes ſhut cloſer, and ſo each of them may take a little hold themſelves on a body; but that is not all, for the under ſides of theſe Soles are all beſet with ſmall briſles, or tenters, like the Wire teeth of a Card uſed for working Wool, the points of all which tend forwards, hence the two Tallons drawing the feet forwards, as I before hinted, and theſe being applied to the ſurface of the body with all the points looking the contrary way, that is, forwards and outwards, if there be any irregularity or yielding in the ſurface of the body, the Fly ſuſpends it ſelf very firmly and eaſily, without the acceſs or need of any ſuch Sponges fill'd with an imaginary *gluten*, as many have, for want of good Glaſſes, perhaps, or a troubleſome and diligent examination, ſuppos'd.

Now, that the Fly is able to walk on Glaſs, proceeds partly from ſome ruggedneſs


Schem XXIII
Fig. 1
B
I
G
G
F
F
D
D
G
G
B
C
I
Fig. 3
Fig. 2
C
A
C
Fig. 4
E
F
B
D



ruggedneſs of the ſurface; and chiefly from a kind of tarniſh, or dirty ſmoaky ſubſtance, which adheres to the ſurface of that very hard body; and though the pointed parts cannot penetrate the ſubſtance of Glaſs, yet may they find pores enough in the tarniſh, or at leaſt make them.

This Structure I ſomewhat the more diligently ſurvey'd, becauſe I could not well comprehend, how, if there were ſuch a glutinous matter in thoſe ſuppoſed Sponges, as moſt (that have obſerv'd that Object in a *Microſcope*) have hitherto believ'd, how, I ſay, the Fly could ſo readily unglew and looſen its feet: and, becauſe I have not found any other creature to have a contrivance any ways like it; and chiefly, that we might not be caſt upon unintelligible explications of the *Phænomena* of Nature, at leaſt others then the true ones, where our ſenſes were able to furniſh us with an intelligible, rationall and true one.

Somewhat a like contrivance to this of Flies ſhall we find in moſt other Animals, ſuch as all kinds of Flies and caſe-wing'd creatures; nay, in a Flea, an Animal abundantly ſmaller then this Fly. Other creatures, as Mites, the Land-Crab, *&c.* have onely one ſmall very ſharp Tallon at the end of each of their legs, which all drawing towards the center or middle of their body, inable theſe exceeding light bodies to ſuſpend and faſten themſelves to almoſt any ſurface.

Which how they are able to do, will not ſeem ſtrange, if we conſider, firſt, how little body there is in one of theſe creatures compar'd to their ſuperficies, or outſide, their thickneſs, perhaps, oftentimes, not amounting to the hundredth part of an Inch: Next, the ſtrength and agility of theſe creatures compar'd to their bulk, being, proportionable to their bulk, perhaps, an hundred times ſtronger then an Horſe or Man. And thirdly, if we conſider that Nature does always appropriate the inſtruments, ſo as they are the moſt fit and convenient to perform their offices, and the moſt ſimple and plain that poſſibly can be; this we may ſee further verify'd alſo in the foot of a Louſe which is very much differing from thoſe I have been deſcribing, but more convenient and neceſſary for the place of its habitation, each of his leggs being footed with a couple of ſmall claws which he can open or ſhut at pleaſure, ſhap'd almoſt like the claws of a Lobſter or Crab, but with appropriated contrivances for his peculiar uſe, which being to move its body to and fro upon the hairs of the creature it inhabits, Nature has furniſh'd one of its claws with joints, almoſt like the joints of a man's fingers, ſo as thereby it is able to encompaſs or graſp a hair as firmly as a man can a ſtick or rope.

Nor, is there a leſs admirable and wonderfull *Mechaniſm* in the foot of a Spider, whereby he is able to ſpin, weave, and climb, or run on his curious tranſparent clew, of which I ſhall ſay more in the deſcription of that Animal.

And to conclude, we ſhall in all things find, that Nature does not onely work Mechanically, but by ſuch excellent and moſt compendious, as well as ſtupendious contrivances, that it were impoſſible for all the reaſon in the world to find out any contrivance to do the ſame thing that ſhould have more convenient properties. And can any be ſo ſottiſh,

as to think all thoſe things the productions of chance? Certainly, either their Ratiocination muſt be extremely depraved, or they did never attentively conſider and contemplate the Works of the Al-mighty.

Obſerv. XXXVIII. *Of the Structure and motion of the Wings of* Flies.

THe Wings of all kinds of Inſects, are, for the moſt part, very beautifull Objects, and afford no leſs pleaſing an Object to the mind to ſpeculate upon, then to the eye to behold. This of the blue Fly, among the reſt, wants not its peculiar ornaments and contrivances; it grows out of the *Thorax*, or middle part of the body of a Fly, and is ſeated a little beyond the center of gravity in the body towards the head, but that *Excentricly* is curiouſly balanc'd; firſt, by the expanded *Area* of the wings which lies all more backwards then the root, by the motion of them, whereby the center of their vibration is much more backwards towards the tail of the Fly then the root of the wing is. What the vibrative motion of the wings is, and after what manner they are moved, I have endeavoured by many trials to find out: And for the firſt manner of their motion, I endeavoured to obſerve ſeveral of thoſe kind of ſmall ſpinning Flies, which will naturally ſuſpend themſelves, as it were, pois'd and ſteady in one place of the air, without riſing or falling, or moving forwards or backwards; for by looking down on thoſe, I could by a kind of faint ſhadow, perceive the utmoſt extremes of the vibrative motion of their wings, which ſhadow, whil'ſt they ſo endeavoured to ſuſpend themſelves, was not very long, but when they endeavour'd to flie forwards, it was ſomewhat longer; next, I tried it, by fixing the leggs of a Fly upon the top of the ſtalk of a feather, with Glew, Wax, *&c.* and then making it endeavour to flie away; for being thereby able to view it in any poſture, I collected that the motion of the wing was after this manner. The extreme limits of the vibrations were uſually ſomewhat about the length of the body diſtant from one another, oftentimes ſhorter, and ſometimes alſo longer; that the formoſt limit was uſually a little above the back, and the hinder ſomwhat beneath the belly; between which two limits, if one may gheſs by the ſound, the wing ſeem'd to be mov'd forwards and backwards with an equal velocity: And if one may (from the ſhadow or faint repreſentation the wings afforded, and from the conſideration of the nature of the thing) gheſs at the poſture or manner of the wings moving betweeen them, it ſeem'd to be this: The wing being ſuppos'd placed in the upmoſt limit, ſeems to be put ſo that the plain of it lies almoſt *horizontal*, but onely the forepart does dip a little, or is ſomewhat more depreſt; in this poſition is the wing vibrated or mov'd to the lower limit, being almoſt arrived at the lower limit, the hinder part of the wing moving ſomewhat faſter then the former,

former, the *Area* of the wing begins to dip behind, and in that posture seems it to be mov'd to the upper limit back again, and thence back again in the first posture, the former part of the *Area* dipping again, as it is moved downwards by means of the quicker motion of the main stem which terminates or edges the forepart of the wing. And these vibrations or motions to and fro between the two limits seem so swift, that 'tis very probable (from the sound it affords, if it be compar'd with the vibration of a musical string, tun'd unison to it) it makes many hundreds, if not some thousands of vibrations in a second minute of time. And, if we may be allow'd to ghess by the sound, the wing of a Bee is yet more swift, for the tone is much more acute, and that, in all likelihood, proceeds from the exceeding swift beating of the air by the small wing. And it seems the more likely too, because the wing of a Bee is less in proportion to its body, then the other wing to the body of a Fly; so that for ought I know, it may be one of the quickest vibrating *spontaneous* motions of any in the world; and though perhaps there may be many Flies in other places that afford a yet more shrill noise with their wings, yet 'tis most probable that the quickest vibrating *spontaneous* motion is to be found in the wing of some creature. Now, if we consider the exceeding quickness of these Animal spirits that must cause these motions, we cannot chuse but admire the exceeding vividness of the governing faculty or *Anima* of the Insect, which is able to dispose and regulate so the the motive faculties, as to cause every peculiar organ, not onely to move or act so quick, but to do it also so regularly.

Whil'st I was examining and considering the curious *Mechanism* of the wings, I observ'd that under the wings of most kind of Flies, Bees, *&c.* there were plac'd certain *pendulums* or extended drops (as I may so call them from their resembling motion and figure) for they much resembled a long hanging drop of some transparent viscous liquor; and I observed them constantly to move just before the wings of the Fly began to move, so that at the first sight I could not but ghess, that there was some excellent use, as to the regulation of the motion of the wing, and did phancy, that it might be something like the handle of a Cock, which by vibrating to and fro, might, as 'twere, open and shut the Cock, and thereby give a passage to the determinate influences into the Muscles; afterwards, upon some other trials, I suppos'd that they might be for some use in respiration, which for many reasons I suppose those Animals to use, and, me thought, it was not very improbable, but that they might have convenient passages under the wings for the emitting, at least, of the air, if not admitting, as in the gills of Fishes is most evident; or, perhaps, this *Pendulum* might be somewhat like the staff to a Pump, whereby these creatures might exercise their *Analogus* lungs, and not only draw in, but force out, the air they live by: but these were but conjectures, and upon further examination seem'd less probable.

The fabrick of the wing, as it appears through a moderately magnifying *Microscope*, seems to be a body consisting of two parts, as is visible in the 4. *Figure* of the 23. *Scheme*; and by the 2. *Figure* of the 26. *Scheme*; the one is a quilly

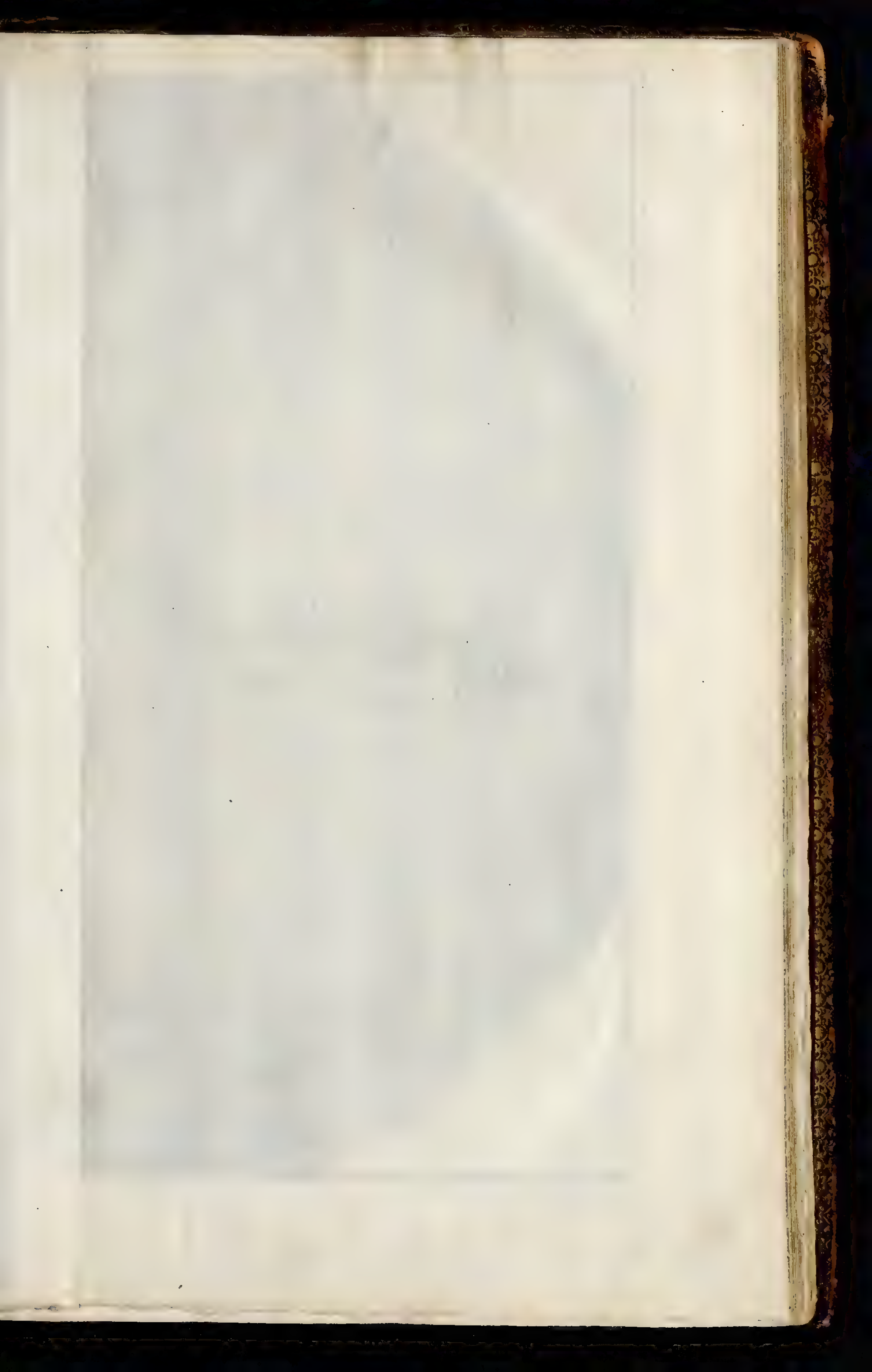
a quilly or finny ſubſtance,conſiſting of ſeveral long,ſlender and variouſly bended quills or wires, ſomething reſembling the veins of leaves; theſe are, as 'twere,the finns or quills which ſtiffen the whole *Area*, and keep the other part diſtended, which is a very thin tranſparent ſkin or membrane variouſly folded, and platted, but not very regularly, and is beſides exceeding thickly beſtuck with innumerable ſmall briſles, which are onely perceptible by the bigger magnifying *Microſcope*, and not with that neither, but with a very convenient augmentation of ſky-light projected on the Object with a burning Glaſs, as I have elſewhere ſhew'd, or by looking through it againſt the light.

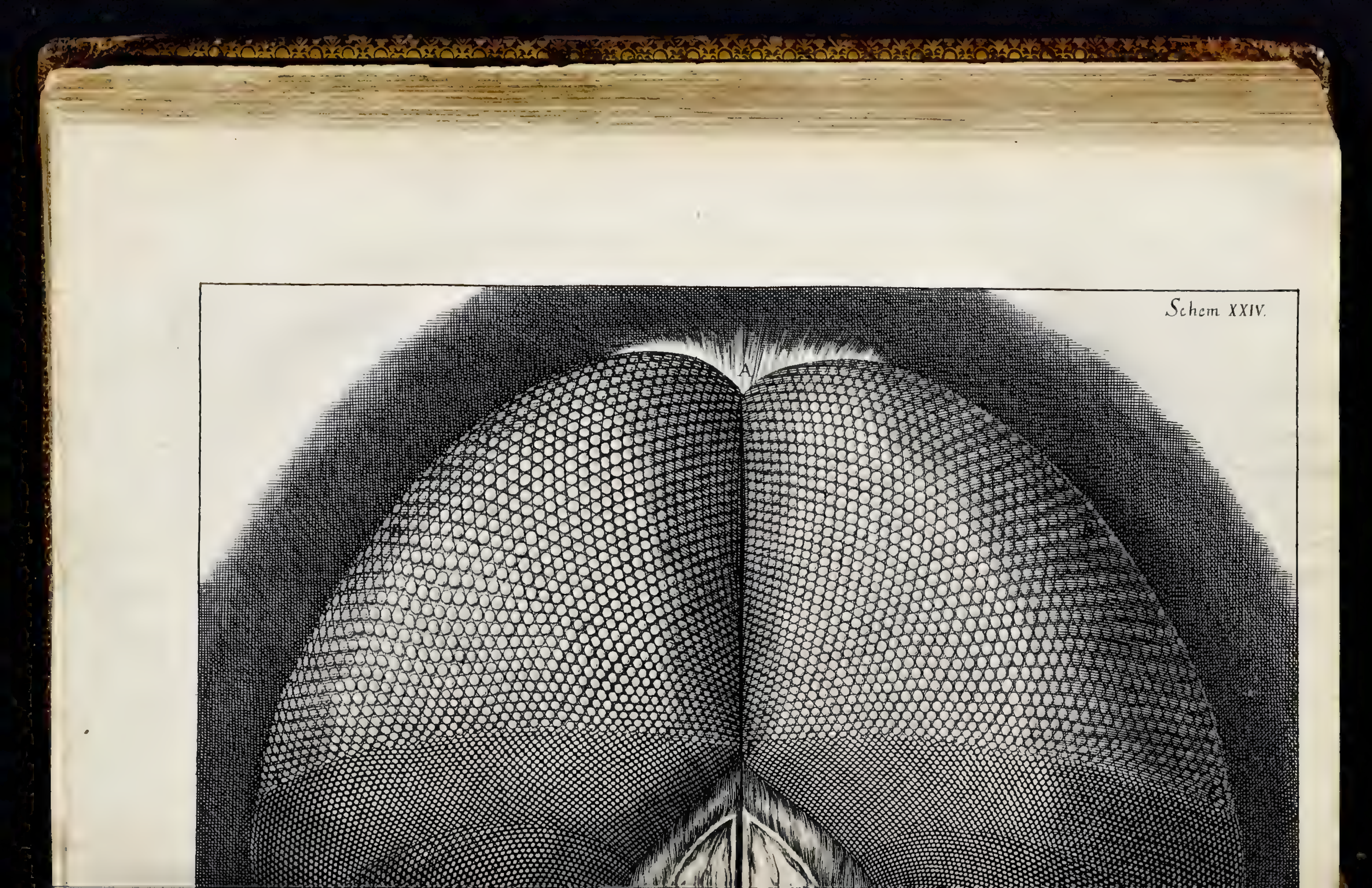
In ſteed of theſe ſmall hairs, in ſeveral other Flies, there are infinite of ſmall Feathers, which cover both the under and upper ſides of this thin film as in almoſt all the ſorts of Butterflies and Moths: and thoſe ſmall parts are not onely ſhap'd very much like the feathers of Birds, but like thoſe variegated with all the variety of curious bright and vivid colours imaginable; and thoſe feathers are likewiſe ſo admirably and delicately rang'd,as to compoſe very fine flouriſhings and ornamental paintings,like *Turkie* and *Perſian* Carpets,but of far more ſurpaſſing beauty, as is evident enough to the naked eye, in the painted wings of Butterflies, but much more through an ordinary *Microſcope*.

Intermingled likewiſe with theſe hairs, may be perceived multitudes of little pits, or black ſpots,in the exended membrane, which ſeem to be the root of the hairs that grow on the other ſide; theſe two bodies ſeem diſpers'd over the whole ſurface of the wing.

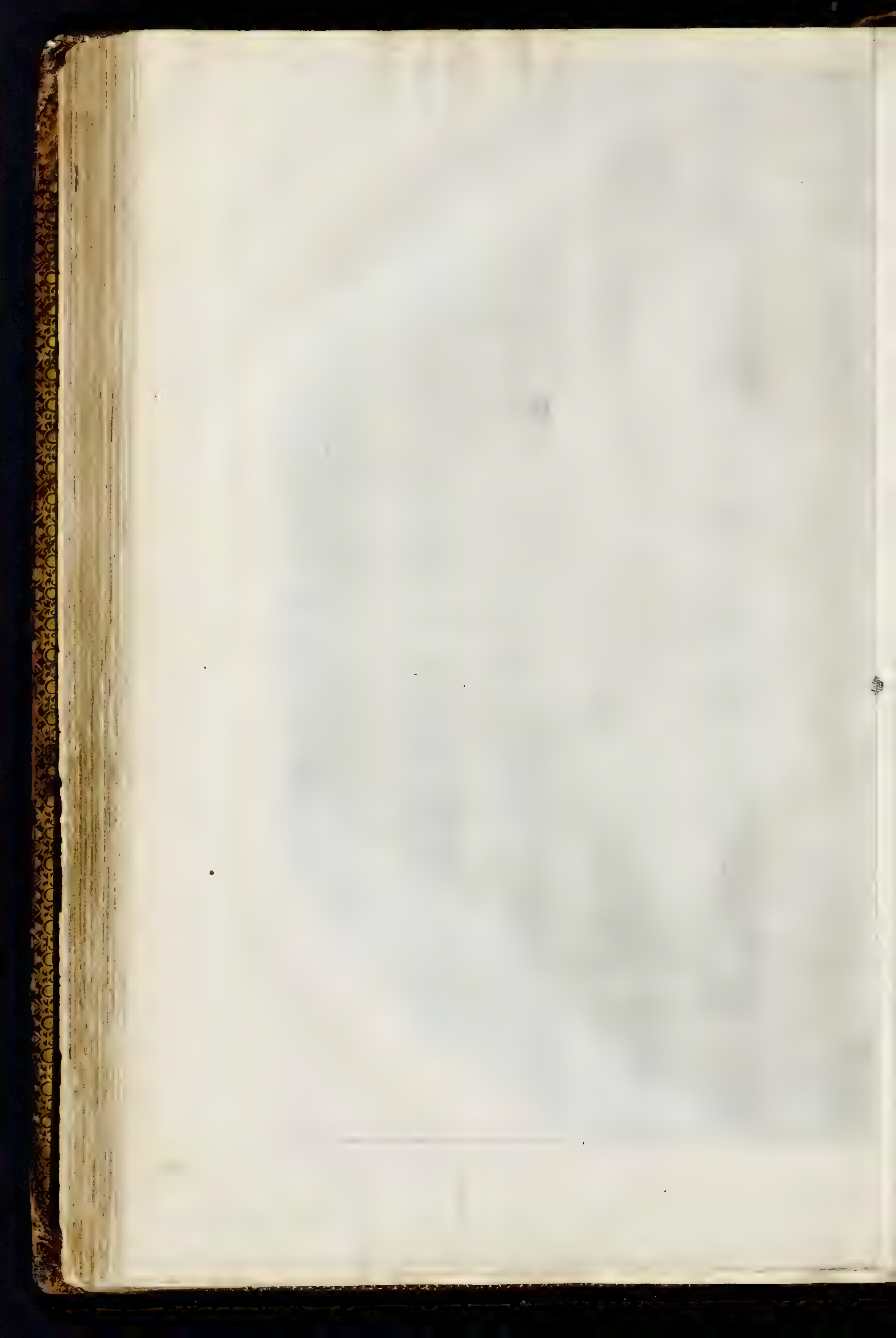
The hairs are beſt perceiv'd, by looking through it againſt the light, or, by laying the wing upon a very white piece of Paper, in a convenient light, for thereby every little hair moſt manifeſtly appears; a *Specimen*t of which you may obſerve drawn in the fourth *Figure* of the 23. *Scheme*, A B, C D, E F whereof repreſent ſome parts of the bones or quills of the wing, each of which you may perceive to be cover'd over with a multitude of ſcales, or briſles, the former A B, is the biggeſt ſtem of all the wing, and may be properly enough call'd the cut-air, it being that which terminates and ſtiffens the formoſt edge of the wing; the fore-edge of this is arm'd with a multitude of little briſles, or Tenter-hooks, in ſome ſtanding regular and in order, in others not; all the points of which are directed from the body towards the tip of the wing, nor is this edge onely thus fring'd, but even all the whole edge of the wing is cover'd with a ſmall fringe, conſiſting of ſhort and more ſlender briſles.

This Subject, had I time, would afford excellent matter for the contemplation of the nature of wings and of flying; but, becauſe I may, perhaps, get a more convenient time to proſecute that ſpeculation, and recollect ſeveral Obſervations that I have made of that particular. I ſhall at preſent proceed to




Schem XXIV.
A





Obſerv. XXXIX. *Of the Eyes and Head of a* Grey drone-Fly, *and of ſeveral other creatures.*

I took a large grey *Drone-Fly*, that had a large head, but a ſmall and ſlender body in proportion to it, and cutting off its head, I fix'd it with the forepart or face upwards upon my Object Plate (this I made choice of rather then the head of a great blue Fly, becauſe my enquiry being now about the eyes, I found this Fly to have, firſt the biggeſt cluſters of eyes in proportion to his head, of any ſmall kind of Fly that I have yet ſeen, it being ſomewhat inclining towards the make of the large *Dragon-Flies*. Next, becauſe there is a greater variety in the knobs or balls of each cluſter, then is of any ſmall Fly) Then examining it according to my uſual manner, by varying the degrees of light, and altering its poſition to each kinde of light, I drew that repreſentation of it which is delineated in the 24. *Scheme*, and found theſe things to be as plain and evident, as notable and pleaſant.

Firſt, that the greateſt part of the face, nay, of the head, was nothing elſe but two large and *protuberant* bunches, or *prominent* parts, A B C D E A, the ſurface of each of which was all cover'd over, or ſhap'd into a multitude of ſmall *Hemiſpheres*, plac'd in a *triagonal* order, that being the cloſeſt and moſt compacted, and in that order, rang'd over the whole ſurface of the eye in very lovely rows, between each of which, as is neceſſary, were left long and regular trenches, the bottoms of every of which, were perfectly intire, and not at all perforated or drill'd through, which I moſt certainly was aſſured of, by the regularly reflected Image of certain Objects which I mov'd to and fro between the head and the light. And by examining the *Cornea* or outward ſkin, after I had ſtript it off from the ſeveral ſubſtances that lay within it, and by looking both upon the inſide and againſt the light.

Next, that of thoſe multitudes of *Hemiſpheres*, there were obſervable two degrees of bigneſs, the half of them that were lowermoſt, and look'd toward the ground or their own leggs, namely, C D E, C D E being a pretty deal ſmaller then the other, namely, A B C E, A B C E, that look'd upward, and ſide-ways, or foreright, and backward, which variety I have not found in any other ſmall Fly.

Thirdly, that every one of theſe *Hemiſpheres*, as they ſeem'd to be pretty neer the true ſhape of a *Hemiſphere*, ſo was the ſurface exceeding ſmooth and regular, reflecting as exact, regular, and perfect an Image of any Object from the ſurface of them, as a ſmall Ball of Quick-ſilver of that bigneſs would do, but nothing neer ſo vivid, the reflection from theſe being very languid, much like the reflection from the outſide of Water, Glaſs, Cryſtal, *&c.* In ſo much that in each of theſe *Hemiſpheres*, I have been able to diſcover a Land-ſcape of thoſe things which lay before my window,

window, one thing of which was a large Tree, whoſe trunk and top I could plainly diſcover, as I could alſo the parts of my window, and my hand and fingers, if I held it between the Window and the Object; a ſmall draught of nineteen of which, as they appear'd in the bigger Magnifying-glaſs to reflect the Image of the two windows of my Chamber, are delineated in the third *Figure* of the 23. *Scheme*.

Fourthly, that theſe rows were ſo diſpos'd, that there was no quarter viſible from his head that there was not ſome of theſe *Hemiſpheres* directed againſt; ſo that a Fly may be truly ſaid to have *an eye every way*, and to be really *circumſpect*. And it was further obſervable, that that way where the trunk of his body did hinder his proſpect backward, theſe *protuberances* were elevated, as it were, above the plain of his ſhoulders and back, ſo that he was able to ſee backwards alſo over his back.

Fifthly, in living Flies, I have obſerv'd, that when any ſmall mote or duſt, which flies up and down the air, chances to light upon any part of theſe knobs, as it is ſure to ſtick firmly to it and not fall, though through the *Microſcope* it appears like a large ſtone or ſtick (which one would admire, eſpecially ſince it is no ways probable that there is any wet or glutinous matter upon theſe *Hemiſpheres*, but I hope I ſhall render the reaſon in another place) ſo the Fly preſently makes uſe of his two fore-feet in ſtead of eye-lids, with which, as with two Brooms or Bruſhes, they being all beſtuck with Briſles, he often ſweeps or bruſhes off what ever hinders the proſpect of any of his *Hemiſpheres*, and then, to free his leggs from that dirt, he rubs them one againſt another, the pointed Briſles or Tenters of which looking both one way, the rubbing of them to and fro one againſt another, does cleanſe them in the ſame manner as I have obſerv'd thoſe that Card Wool, to cleanſe their Cards, by placing their Cards, ſo as the teeth of both look the ſame way, and then rubbing them one againſt another. In the very ſame manner do they bruſh and cleanſe their bodies and wings, as I ſhall by and by ſhew; other creatures have other contrivances for the cleanſing and cleering their eyes.

Sixthly, that the number of the *Pearls* or *Hemiſpheres* in the cluſters of this Fly, was neer 14000. which I judged by numbering certain rows of them ſeveral ways, and caſting up the whole content, accounting each cluſter to contain about ſeven thouſand Pearls, three thouſand of which were of a cize, and conſequently the rows not ſo thick, and the foure thouſand I accounted to be the number of the ſmaller Pearls next the feet and *proboſcis*. Other Animals I obſerv'd to have yet a greater number, as the *Dragon-Fly* or *Adderbolt*: And others to have a much leſs company, as an *Ant*, &c. and ſeveral other ſmall Flies and Inſects.

Seventhly, that the order of theſe eies or *Hemiſpheres* was altogether curious and admirable, they being plac'd in all kind of Flies, and *aerial* animals, in a moſt curious and regular ordination of triangular rows, in which order they are rang'd the neereſt together that poſſibly they can, and conſequently leave the leaſt pits or trenches between them. But in *Shrimps*, *Crawfiſhes*, *Lobſters*, and ſuch kinds of *Cruſtaceous* water Animals, I have yet

yet obſerv'd them rang'd in a quadrangular order, the rows cutting each other at right angles,which as it admits of a leſs number of Pearls in equal ſurfaces; ſo have thoſe creatures a recompence made them, by having their eyes a little movable in their heads, which the other altogether want. So infinitely wiſe and provident do we find all the Diſpenſations in Nature, that certainly *Epicurus*, and his followers, muſt very little have conſider'd them, who aſcrib'd thoſe things to the production of chance, that wil,to a more attentive conſiderer,appear the products of the higheſt Wiſdom and Providence.

Upon the Anatomy or Diſſection of the Head, I obſerv'd theſe particulars:

Firſt, that this outward ſkin, like the *Cornea* of the eyes of the greater Animals, was both flexible and tranſparent, and ſeem'd, through the *Microſcope*, perfectly to reſemble the very ſubſtance of the *Cornea* of a man's eye; for having cut out the cluſter, and remov'd the dark and *mucous* ſtuff that is ſubjacent to it, I could ſee it tranſparent like a thin piece of ſkin, having as many cavities in the inſide of it, and rang'd in the ſame order as it had *protuberances* on the outſide,and this propriety,I found the ſame in all the Animals that had it, whether Flies or Shell-Fiſh.

Secondly, I found that all Animals that I have obſerv'd with thoſe kind of eyes, have within this *Cornea*, a certain cleer liquor or juice, though in a very little quantity, and,

I obſerv'd thirdly, that within that cleer liquor, they had a kind of dark *mucous* lining, which was all ſpread round within the cavity of the cluſter, and ſeem'd very neer adjoining to it, the colour of which, in ſome Flies,was grey; in others, black; in others red; in others,of a mix'd colour; in others,ſpotted; and that the whole cluſters, when look'd on whil'ſt the Animal was living, or but newly kill'd, appear'd of the ſame colour that this coat (as I may ſo call it) appear'd of, when that outward ſkin, or *Cornea*,was remov'd.

Fourthly, that the reſt of the capacity of the cluſters was in ſome, as in Dragon Flies, *&c.* hollow, or empty; in others fill'd with ſome kind of ſubſtance; in blue Flies,with a reddiſh muſculous ſubſtance, with *fibres* tending from the center or bottom outwards; and divers other,with various and differing kinds of ſubſtances.

That this curious contrivance is the organ of ſight to all thoſe various *Cruſtaceous* Animals, which are furniſh'd with it, I think we need not doubt, if we conſider but the ſeveral congruities it has with the eyes of greater creatures.

As firſt, that it is furniſh'd with a *Cornea*,with a *tranſparent humour*,and with a *uvea* or *retina*, that the Figure of each of the ſmall *Hemiſpheres* are very *Spherical*, exactly poliſh'd, and moſt vivid, lively and plump,when the Animal is living,as in greater Animals,and in like manner dull,flaccid, and irregular, or ſhrunk,when the Animal is dead.

Next, that thoſe creatures that are furniſh'd with it, have no other organs that have any reſemblance to the known eyes of other creatures.

 Thirdly,

Thirdly, that thoſe which they call the eyes of Crabs, Lobſters, Shrimps, and the like, and are really ſo, are *Hemiſpher'd*, almoſt in the ſame manner as theſe of Flies are. And that they really are ſo, I have very often try'd, by cutting off theſe little movable knobs, and putting the creature again into the water, that it would ſwim to and fro, and move up and down as well as before, but would often hit it ſelf againſt the rocks or ſtones; and though I put my hand juſt before its head, it would not at all ſtart or fly back till I touch'd it, whereas whil'ſt thoſe were remaining, it would ſtart back, and avoid my hand or a ſtick at a good diſtance before it touch'd it. And if in *cruſtaceous* Sea-animals, then it ſeems very probable alſo, that theſe knobs are the eyes in *cruſtaceous* Inſects, which are alſo of the ſame kind, onely in a higher and more active Element; this the conformity or congruity of many other parts common to either of them, will ſtrongly argue, their *cruſtaceous* armour, their number of leggs, which are ſix, beſide the two great claws, which anſwer to the wings in Inſects; and in all kind of Spiders, as alſo in many other Inſects that want wings, we ſhall find the compleat number of them, and not onely the number, but the very ſhape, figure, joints, and claws of Lobſters and Crabs, as is evident in Scorpions and Spiders, as is viſible in the ſecond *Figure* of the 31. *Scheme*, and in the little Mite-worm, which I call a Land-crab, deſcrib'd in the ſecond Figure of the 33. *Scheme*, but in their manner of generation being oviparous, *&c.* And it were very worthy obſervation, whether there be not ſome kinds of transformation and metamorphoſis in the ſeveral ſtates of *cruſtaceous* water-animals, as there is in ſeveral ſorts of Inſects; for if ſuch could be met with, the progreſs of the variations would be much more conſpicuous in thoſe larger Animals, then they can be in any kind of Inſects our colder Climate affords.

Theſe being their eyes, it affords us a very pretty Speculation to contemplate their manner of viſion, which, as it is very differing from that of *biocular* Animals, ſo is it not leſs admirable.

That each of theſe Pearls or *Hemiſpheres* is a perfect eye, I think we need not doubt, if we conſider onely the outſide or figure of any one of them, for they being each of them cover'd with a tranſparent protuberant *Cornea*, and containing a liquor within them, reſembling the watry or glaſſie humours of the eye, muſt neceſſarily refract all the parallel Rays that fall on them out of the air, into a point not farr diſtant within them, where (in all probability) the *Retina* of the eye is placed, and that opacous, dark, and mucous inward coat that (I formerly ſhew'd) I found to ſubtend the concave part of the cluſter is very likely to be that *tunicle* or coat, it appearing through the *Microſcope* to be plac'd a little more than a Diameter of thoſe Pearls below or within the *tunica cornea*. And if ſo, then is there in all probability, a little Picture or Image of the objects without, painted or made at the bottom of the *Retina* againſt every one of thoſe Pearls, ſo that there are as many impreſſions on the *Retina* or opacous ſkin, as there are Pearls or *Hemiſpheres* on the cluſter. But becauſe it is impoſſible for any protuberant ſurface whatſoever, whether *ſphærial* or other, ſo to refract the Rays that come from farr remote

lateral

lateral points of any Object as to collect them again,and unite them each in a distinct point,and that onely those Rays which come from some point that lies in the *Axis* of the Figure produc'd, are so accurately refracted to one and the same point again, and that the *lateral* Rays,the further they are remov'd, the more imperfect is their refracted confluence; It follows therefore, that onely the Picture of those parts of the external objects that lie in, or neer, the *Axis* of each *Hemisphere*, are discernably painted or made on the *Retina* of each *Hemisphere*, and that therefore each of them can distinctlysensate or see onely those parts which are very neer perpendicularly oppos'd to it, or lie in or neer its optick *Axis*: Now, though there may be by each of these eye-pearls,a representation to the Animal of a whole *Hemisphere* in the same manner as in a man's eye there is a picture or sensation in the *Retina* of all the objects lying almost in an *Hemisphere*; yet, as in a man's eye also, there are but some very few points which liyng in, or neer, the optick *Axis* are distinctly discern'd: So there may be multitudes of Pictures made of an Object in the several Pearls, and yet but one, or some very few that are distinct; The representation of any object that is made in any other Pearl, but that which is directly,or very neer directly,oppos'd,being altogether confus'd and unable to produce a distinct vision.

So that we see,that though it has pleas'd the All-wise Creator, to indue this creature with such multitudes of eyes, yet has he not indued it with the faculty of seeing more then another creature; for whereas this cannot move his head,at least can move itvery little,without moving his whole body, *biocular* creatures can in an instant (or *the twinkling of an eye*, which, being very quick, is vulgarly used in the same signification) move their eyes so as to direct the optick *Axis* to any point; nor is it probable, that they are able to see attentively at one time more then one Physical point; for though there be a distinct Image made in every eye, yet 'tis very likely,that the observing faculty is only imploy'd about some one object for which they have most concern.

Now, as we accurately distinguish the site or position of an Object by the motion of the Muscles of the eye requisite to put the optick Line in a direct position,and confusedly by the position of the imperfect Picture of the object at the bottom of the eye; so are these *crustaceous* creatures able to judge confusedly of the position of objects by the Picture or impression made at the bottom of the opposite Pearl, and distinctly by the removal of the attentive or observing faculty, from one Pearl to another; but what this faculty is,as it requires another place, so a much deeper speculation. Now,becauseit were impossible,even with this multitude of eyeballs,to see any object distinct(for as I hinted before,onely those parts that lay in,or veryneer,the optick Lines could be so)the Infinitely wise Creator has not left the creature without a power of moving the head a little in *Aerial crustaceous* animals,and the very eyes also in *crustaceous* Sea-animals; so that by these means they are inabled to direct some optick line or other against any object,and by that means they have the visive faculty as compleat as any Animal that can move its eyes.

Diſtances of Objects alſo, 'tis very likely they diſtinguiſh, partly by the conſonant impreſſions made in ſome two convenient Pearls, one in each cluſter; for, according as thoſe congruous impreſſions affect, two Pearls neerer approach'd to each other, the neerer is the Object, and the farther they are diſtant, the more diſtant is the Object: partly alſo by the alteration of each Pearl, requiſite to make the Senſation or Picture perfect; for 'tis impoſſible that the Pictures of two Objects, variouſly diſtant, can be perfectly painted, or made on the ſame *Retina* or bottom of the eye not altered, as will be very evident to any one that ſhall attentively conſider the nature of refraction. Now, whether this alteration may be in the Figure of the *Cornea*, in the motion of acceſs or receſs of the *Retina* towards the *Cornea*, or in the alteration of a cruſtaline humour, if ſuch there be, I pretend not to determine; though I think we need not doubt, but that there may be as much curioſity of contrivance and ſtructure in every one of theſe Pearls, as in the eye of a Whale or Elephant, and the almighty's *Fiat* could as eaſily cauſe the exiſtence of the one as the other; and as one day and a thouſand years are the ſame with him, ſo may one eye and ten thouſand.

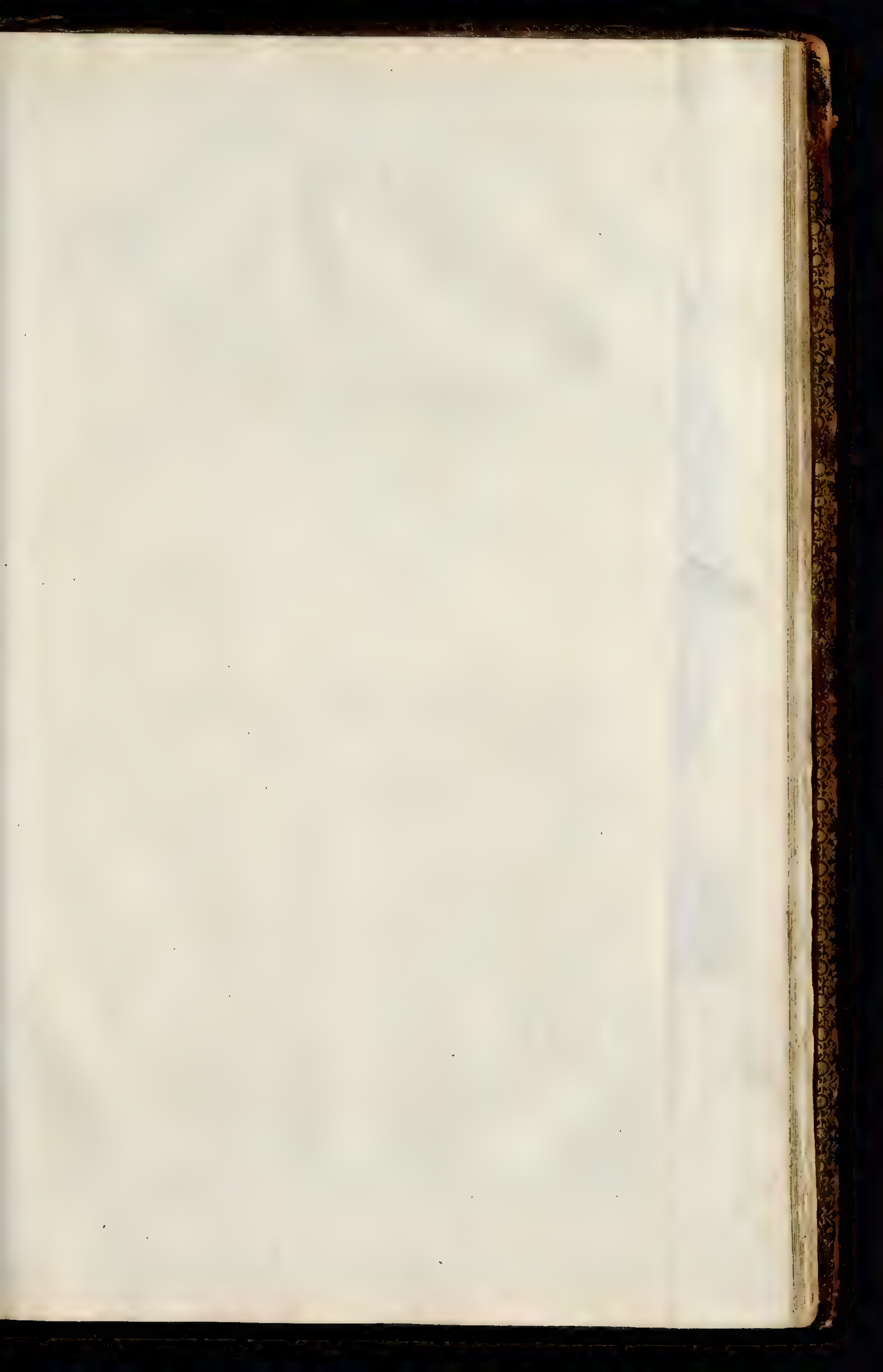
This we may be ſure of, that the filaments or ſenſative parts of the *Retina* muſt be moſt exceedingly curious and minute, ſince the whole Picture it ſelf is ſuch; what muſt needs the component parts be of that *Retina* which diſtinguiſhes the part of an object's Picture that muſt be many millions of millions leſs then that in a man's eye? And how exceeding curious and ſubtile muſt the component parts of the *medium* that conveys light be, when we find the inſtrument made for its reception or refraction to be ſo exceedingly ſmall? we may, I think, from this ſpeculation be ſufficiently diſcouraged from hoping to diſcover by any optick or other inſtrument the determinate bulk of the parts of the *medium* that conveys the pulſe of light, ſince we find that there is not leſs accurateneſs ſhewn in the Figure and poliſh of thoſe exceedingly minute lenticular ſurfaces, then in thoſe more large and conſpicuous ſurfaces of our own eyes. And yet can I not doubt, but that there is a determinate bulk of thoſe parts, ſince I find them unable to enter between the parts of Mercury, which being in motion, muſt neceſſarily have pores, as I ſhall elſewhere ſhew, and here paſs by, as being a digreſſion.

As concerning the horns F F, the feelers or ſmellers, G G, the *Proboſcis* H H, and I, the hairs and briſles, K K, I ſhall indeavour to deſcribe in the 42. *Obſervation*.

Obſerv. X L. *Of the Teeth of a* Snail.

I Have little more to add of the Teeth of a Snail, beſides the Picture of it, which is repreſented in the firſt *Figure* of the 25. *Scheme*, ſave that his bended body, A B C D E F, which ſeem'd faſhioned very much like a row of ſmall teeth, orderly plac'd in the Gums, and looks as if it

were



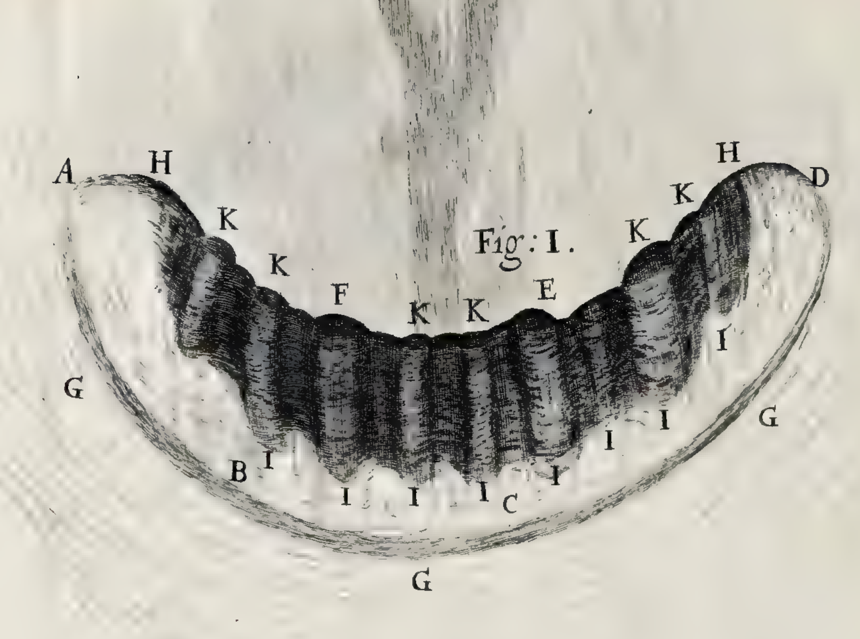






Fig: 3.

were divided into ſeveral ſmaller and greater black teeth, was nothing but one ſmall bended hard bone,which was plac'd in the upper jaw of the mouth of a Houſe-Snail, with which I obſerv'd this very Snail to feed on the leaves of a Roſe-tree, and to bite out pretty large and half round bits, not unlike the Figure of a (C) nor very much differing from it in bigneſs, the upper part A B C D of this bone, I found to be much whiter, and to grow out of the upper chap of the Snail G G G,and not to be any thing neer ſo much creas'd as the lower and blacker part of it H I I H K K H which was exactly ſhap'd like teeth, the bone growing thinner, or tapering to an edge towards K K K. It ſeem'd to have nine teeth, or prominent parts I K, I K, I F, *&c.* which were join'd together by the thinner interpos'd parts of the bone. The Animal to which theſe teeth belong, is a very *anomalous* creature, and ſeems of a kind quite diſtinct from any other terreſtrial Animal or Inſect, the Anatomy whereof exceedingly differing from what has been hitherto given of it I ſhould have inſerted,but that it will be more proper in another place. I have never met with any kind of Animal whoſe teeth are all join'd in one, ſave onely that I lately obſerv'd, that all the teeth of a Rhinocerot, which grow on either ſide of its mouth, are join'd into one large bone, the weight of one of which I found to be neer eleven pound *Haverdupois.* So that it ſeems one of the biggeſt ſort of terreſtrial Animals, as well as one of the ſmalleſt, has his teeth thus ſhap'd.

Obſerv. XLI. *Of the Eggs of* Silk-worms,*and other Inſects.*

THe Eggs of Silk-worms(one of which I have deſcrib'd in the ſecond *Figure* of 25. *Scheme*) afford a pretty Object for a *Microſcope* that magnifies very much, eſpecially if it be bright weather, and the light of a window be caſt or collected on it by a deep *Convex-glaſs*, or Water-ball. For then the whole ſurface of the Shell may be perceiv'd all cover'd over with exceeding ſmall pits or cavities with interpoſed edges, almoſt in the manner of the ſurface of a Poppy-ſeed,but that theſe holes are not an hundredth part ſcarce of their bigneſs; the Shell,when the young ones were hatch'd (which I found an eaſie thing to do, if the Eggs were kept in a warm place) appear'd no thicker in proportion to its bulk,then that of an Hen's or Goos's Egg is to its bulk,and all the Shell appear'd very white (which ſeem'd to proceed from its tranſparency) whence all thoſe pittings did almoſt vaniſh, ſo that they could not, without much difficulty, be diſcern'd, the inſide of the Shell ſeem'd to be lin'd alſo with a kind of thin film,not unlike (keeping the proportion to its Shell)that with which the ſhell of an Hen-egg is lin'd ; and the ſhell it ſelf ſeem'd like common Egg-ſhells, very brittle, and crack'd. In divers other of theſe Eggs I could plainly enough, through the ſhell, perceive the ſmall Inſect lie coyled round the edges of the ſhell. The ſhape of the Egg it ſelf, the Figure pretty well repreſents (though by default of the Graver it does

not

not appear ſo rounded, and lying above the Paper, as it were,as it ought to do) that is, it was for the moſt part pretty oval end-ways, ſomewhat like an Egg,but the other way it was a little flatted on two oppoſite ſides. Divers of theſe Eggs, as is common to moſt others, I found to be barren, or addle, for they never afforded any young ones. And thoſe I uſually found much whiter then the other that were prolifick. The Eggs of other kinds of Oviparous Inſects I have found to be perfectly round every way,like ſo many Globules,of this ſort I have obſerv'd ſome ſorts of Spiders Eggs; and chancing the laſt Summer to incloſe a very large and curiouſly painted Butterfly in a Box, intending to examine its gaudery with my *Microſcope*, I found within a day or two after I inclos'd her, almoſt all the inner ſurface of the Box cover'd over with an infinite of exactly round Eggs, which were ſtuck very faſt to the ſides of it, and in ſo exactly regular and cloſe an order, that made me call to mind my *Hypotheſis*, which I had formerly thought on for the making out of all the regular Figures of Salt,which I have elſewhere hinted ; for here I found all of them rang'd into a moſt exact *triagonal* order, much after the manner as the *Hemiſpheres* are place on the eye of a Fly; all which Eggs I found after a little time to be hatch'd, and out of them to come a multitude of ſmall Worms, very much reſembling young Silk-worms, leaving all their thin hollow ſhells behind them, ſticking on the Box in their *triagonal* poſture; theſe I found with the *Microſcope* to have much ſuch a ſubſtance as the Silk-worms Eggs, but could not perceive them pitted. And indeed, there is as great a variety in the ſhape of the Eggs of Oviparous Inſects as among thoſe of Birds.

Of theſe Eggs, a large and luſty Fly will at one time lay neer four or five hundred, ſo that the increaſe of theſe kind of Inſects muſt needs be very prodigious, were they not prey'd on by multitudes of Birds, and deſtroy'd by Froſts and Rains; and hence 'tis thoſe hotter Climates between the *Tropicks* are infeſted with ſuch multitudes of Locuſts, and ſuch other Vermine.

Obſerv. XLII. *Of a blue* Fly.

THis kind of Fly,whereof a *Microſcopical* Picture is delineated in the firſt *Figure* of the 26. *Scheme*, is a very beautifull creature, and has many things about it very notable ; divers of which I have already partly deſcrib'd, namely, the feet, wings, eyes, and head, in the preceding Obſervations.

And though the head before deſcrib'd be that of a grey *Drone-Fly*, yet for the main it is very agreeable to this. The things wherein they differ moſt, will be eaſily enough found by the following particulars:

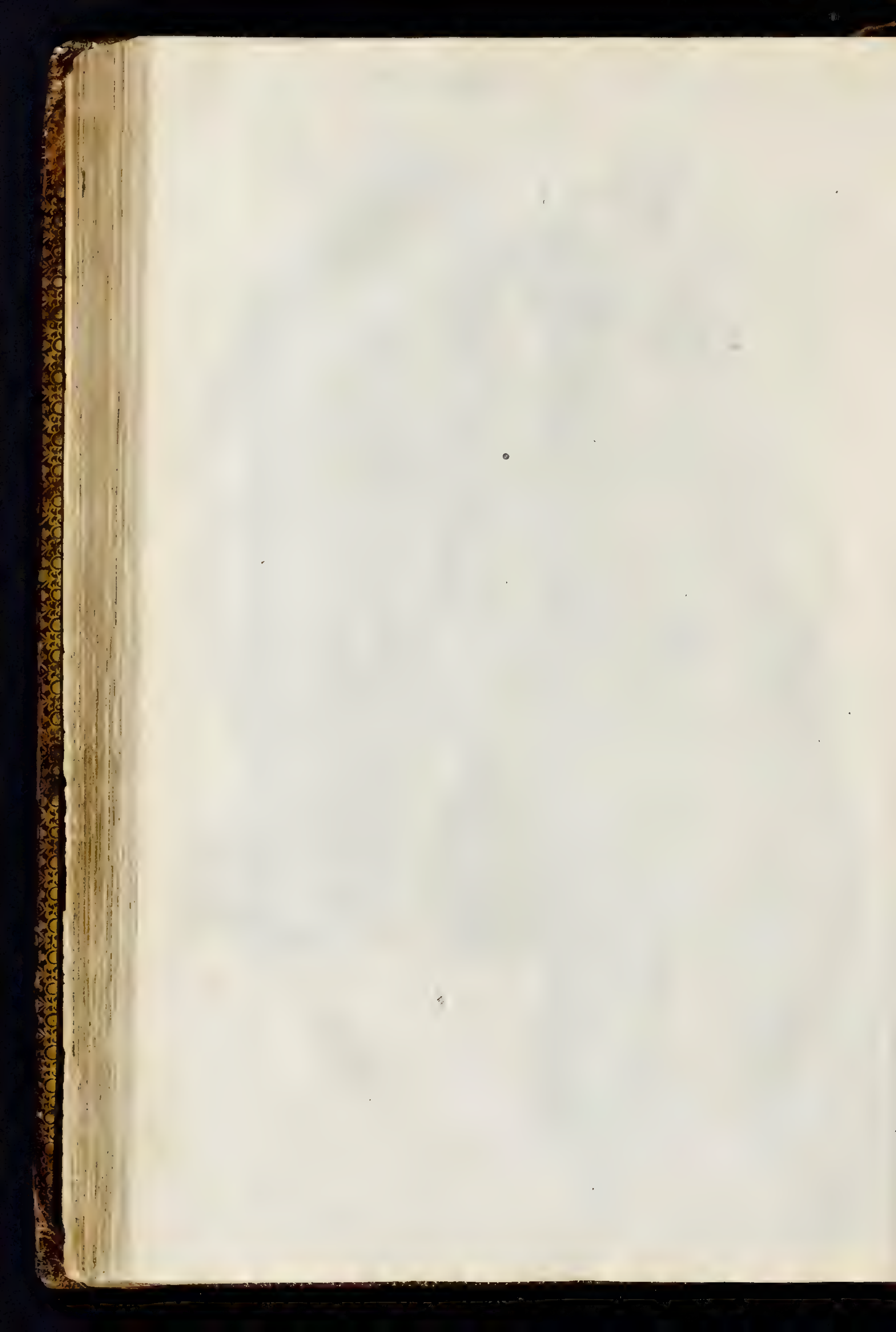
Firſt, the cluſters of eyes of this Fly, are very much ſmaller then thoſe of the *Dron-Fly*, in proportion to the head.

And

Schem: XXVI.

Fig: 1.

Fig: 2.



And next, all the eyes of each cluster seem'd much of the same bigness one with another, not differing as the other, but rang'd in the same *tri-agonal* order.

Thirdly, between these two clusters, there was a scaly prominent *front* B, which was arm'd and adorn'd with large tapering sharp black brisles, which growing out in rows on either side, were so bent toward each other neer the top, as to make a kind of arched arbour of Brisles, which almost cover'd the former *front*.

Fourthly, at the end of this Arch, about the middle of the face, on a prominent part C, grew two small oblong bodies, D D, which through a *Microscope* look'd not unlike the Pendants in Lillies, these seem'd to be jointed on to two small parts at C, each of which seem'd again jointed into the front.

Fifthly, out of the upper part and outsides of these horns (as I may call them, from the Figure they are of, in the 24. *Scheme*, where they are marked with F F) there grows a single feather, or brushy Brisle, E E, somewhat of the same kind with the tufts of a Gnat, which I have before described.

What the use of these kind of horned and tufted bodies should be, I cannot well imagine, unless they serve for smelling or hearing, though how they are adapted for either, it seems very difficult to describe they are in almost every several kind of Flies of so various a shape; though certainly they are some very essential part of the head, and have some very notable office assign'd them by Nature, since in all Insects they are to be found in one or other form.

Sixthly, at the under part of the face F F, were several of the former sort of bended Brisles; and below all, the mouth, out of the middle of which, grew the *proboscis* G H I, which, by means of several joints, whereof it seem'd to consist, the Fly was able to move to and fro, and thrust it in and out as it pleas'd; the end of this hollow body (which was all over cover'd with small short hairs or brisles) was, as 'twere, bent at H, and the outer or formost side of the bended part H I, slit, as it were, into two chaps, H I, H I, all the outside of which where cover'd with hairs, and pretty large brisles; these he could, like two chaps, very readily open and shut, and when he seem'd to suck any thing from the surface of a body, he would spread abroad those chaps, and apply the hollow part of them very close to it.

From either side of the *Proboscis*, within the mouth, grew two other small horns, or fingers, K K, which were hairy, but small in this Figure; but of another shape, and bigger in proportion, in the 24. *Scheme*, where they are marked with G G, which two indeed seem'd a kind of smellers, but whether so or not, I cannot positively determine.

The *Thorax* or middle part of this Fly, was cas'd, both above and beneath, with a very firm crust of armour, the upper part more round, and covered over with long *conical* brisles, all whose ends pointed backwards; out of the hinder and under part of this grew out in a cluster six leggs, three of which are apparent in the Figure, the other three were hid by the body

body plac'd in that poſture. The leggs were all much of the ſame make, being all of them cover'd with a ſtrong hairy ſcale or ſhel, juſt like the legs of a Crabb or Lobſter, and the contrivance of the joints ſeem'd much the ſame; each legg ſeem'd made up of eight parts, 1, 2, 3, 4, 5, 6, 7, 8, to the eighth or laſt of which, grew the ſoles and claws, deſcribed before in the 38. *Obſervation*.

Out of the upper part of this trunck grew the two wings, which I mention'd in the 38. *Obſervation*, conſiſting of a film, extended on certain ſmall ſtiff wires or bones: theſe in a blue Fly, were much longer then the body, but in other kind of Flies they are of very differing proportions to the body. Theſe films, in many Flies, were ſo thin, that, like ſeveral other plated bodies (mention'd in the ninth *Obſervation*) they afforded all varieties of fantaſtical or tranſient colours (the reaſon of which I have here endeavoured to explain) they ſeem'd to receive their nouriſhment from the ſtalks or wires, which ſeem'd to be hollow, and neer the upper part of the wing LL ſeveral of them ſeem'd jointed, the ſhape of which will ſufficiently appear by the black lines in the ſecond Figure of the 26. *Scheme*, which is a delineation of one of thoſe wings expanded directly to the eyes.

All the hinder part of its body is cover'd with a moſt curious blue ſhining armour, looking exactly like a poliſh'd piece of ſteel brought to that blue colour by annealing, all which armour is very thick beſtuck with abundance of tapering briſles, ſuch as grow on its back, as is viſible enough by the Figure.

Nor was the inſide of this creature leſs beautifull then its outſide, for cutting off a part of the belly, and then viewing it, to ſee if I could diſcover any Veſſels, ſuch as are to be found in a greater Animals, and even in Snails exceeding manifeſtly, I found, much beyond my expectation, that there were abundance of branchings of Milk-white veſſels, no leſs curious then the branchings of veins and arteries in bigger terreſtrial Animals, in one of which, I found two notable branches, joining their two main ſtocks, as it were, into one common *ductus*; now, to what veins or arteries theſe Veſſells were *analogus*, whether to the *vena porta*, or the *meſeraick veſſells*, or the like, or indeed, whether they were veins and arteries, or *vaſa lactea*, properly ſo called, I am not hitherto able to determine, having not yet made ſufficient enquiry; but in all particulars, there ſeems not to be any thing leſs of curious contrivance in theſe Inſects, then in thoſe larger terreſtrial Animals, for I had never ſeen any more curious branchings of Veſſells, then thoſe I obſerv'd in two or three of theſe Flies thus opened.

It is a creature active and nimble, ſo as there are very few creatures like it, whether bigger or ſmaller, in ſo much, that it will ſcape and avoid a ſmall body, though coming on it exceeding ſwiftly, and if it ſees any thing approaching it, which it fears, it preſently ſquats down, as it were, that it may be the more ready for its riſe.

Nor is it leſs hardy in the Winter, then active in the Summer, induring all the Froſts, and ſurviving till the next Summer, notwithſtanding the bitter

bitter cold of our Climate; nay, this creature will indure to be frozen, and yet not be destroy'd, for I have taken one of them out of the Snow whereon it has been frozen almost white, with the Ice about it, and yet by thawing it gently by the warmth of a fire, it has quickly reviv'd and flown about.

This kind of Fly seems by the steams or taste of fermenting and putrifying meat (which it often kisses, as'twere, with its *proboscis* as it trips over it) to be stimulated or excited to eject its Eggs or Seed on it, perhaps, from the same reason as Dogs, Cats, and many other brute creatures are excited to their particular lusts, by the smell of their females, when by Nature prepared for generation; the males seeming by those kind of smells, or other incitations, to be as much necessitated thereto, as *Aqua Regis* strongly impregnated with a solution of Gold, is forced to precipitate it by the affusion of spirit of *Urine*, or a solution of *Salt* of *Tartar*.

One of these put in spirit of *Wine*, was very quickly seemingly kill'd, and both its eys and mouth began to look very red, but upon the taking of it out, and suffering it to lie three or four hours, and heating it with the Sun beams cast through a Burning-glass, it again reviv'd, seeming, as it were, to have been all the intermediate time, but dead drunk, and after certain hours to grow fresh again and sober.

Observ. XLIII. *Of the* Water-Insect *or* Gnat.

This little creature, described in the first *Figure* of the 27. *Scheme*, was a small scaled or crusted Animal, which I have often observ'd to be generated in Rain-water; I have also observ'd it both in Pond and River-water. It is suppos'd by some, to deduce its first original from the putrifaction of Rain-water, in which, if it have stood any time open to the air, you shall seldom miss, all the Summer long, of store of them frisking too and fro.

'Tis a creature, wholly differing in shape from any I ever observ'd; nor is its motion less strange: It has a very large head, in proportion to its body, all covered with a shell, like other *testaceous* Animals, but it differs in this, that it has, up and down several parts of it, several tufts of hairs, or brisles, plac'd in the order express'd in the Figure; It has two horns, which seem'd almost like the horns of an Oxe, inverted, and, as neer as I could ghess, were hollow, with tufts of brisles, likewise at the top; these horns they could move easily this or that way, and might, perchance, be their nostrils. It has a pretty large mouth, which seem'd contriv'd much like those of Crabs and Lobsters, by which, I have often observ'd them to feed on water, or some imperceptible nutritive substance in it.

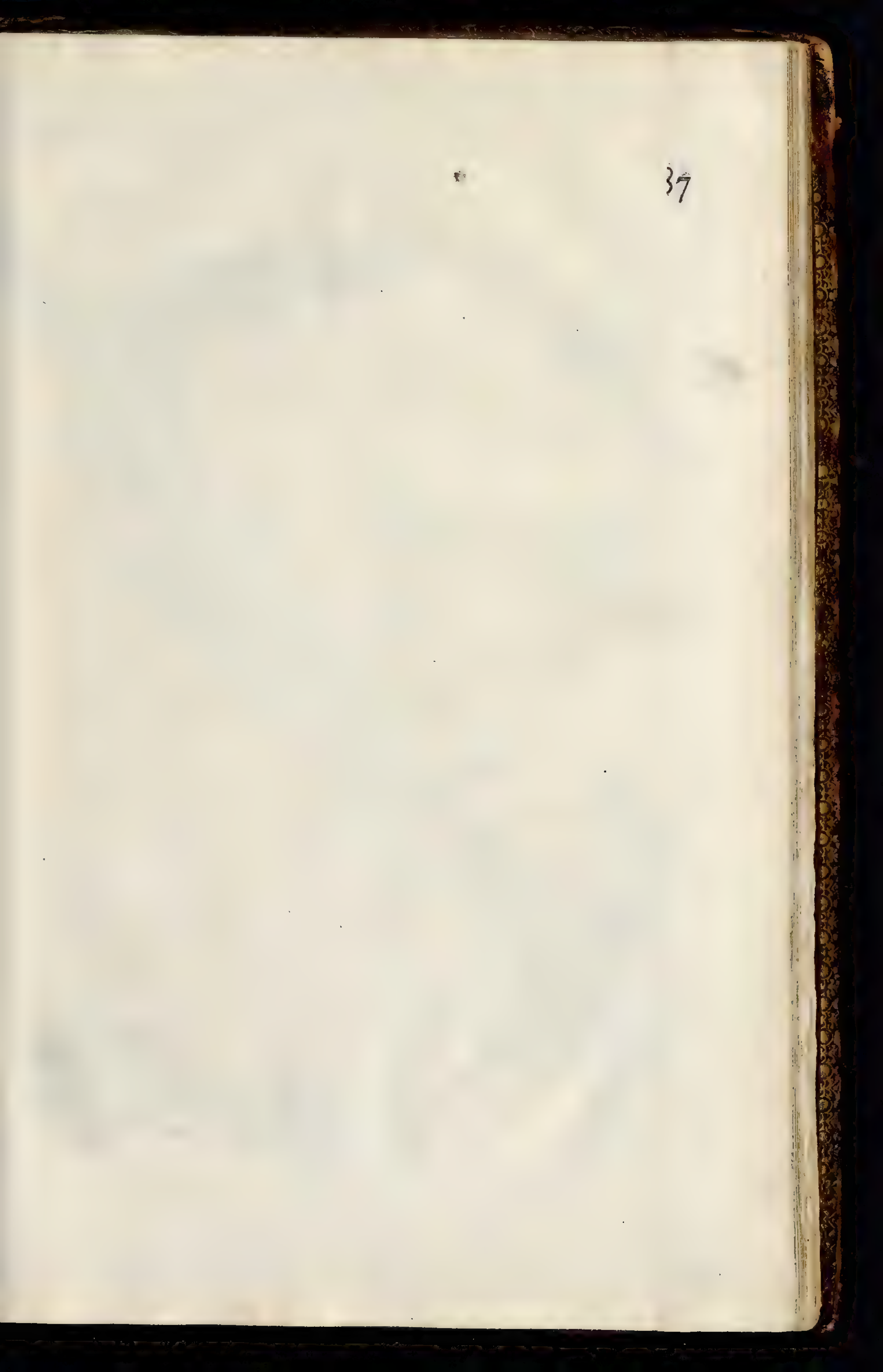
I could perceive, through the transparent shell, while the Animal surviv'd, several motions in the head, thorax, and belly, very distinctly,

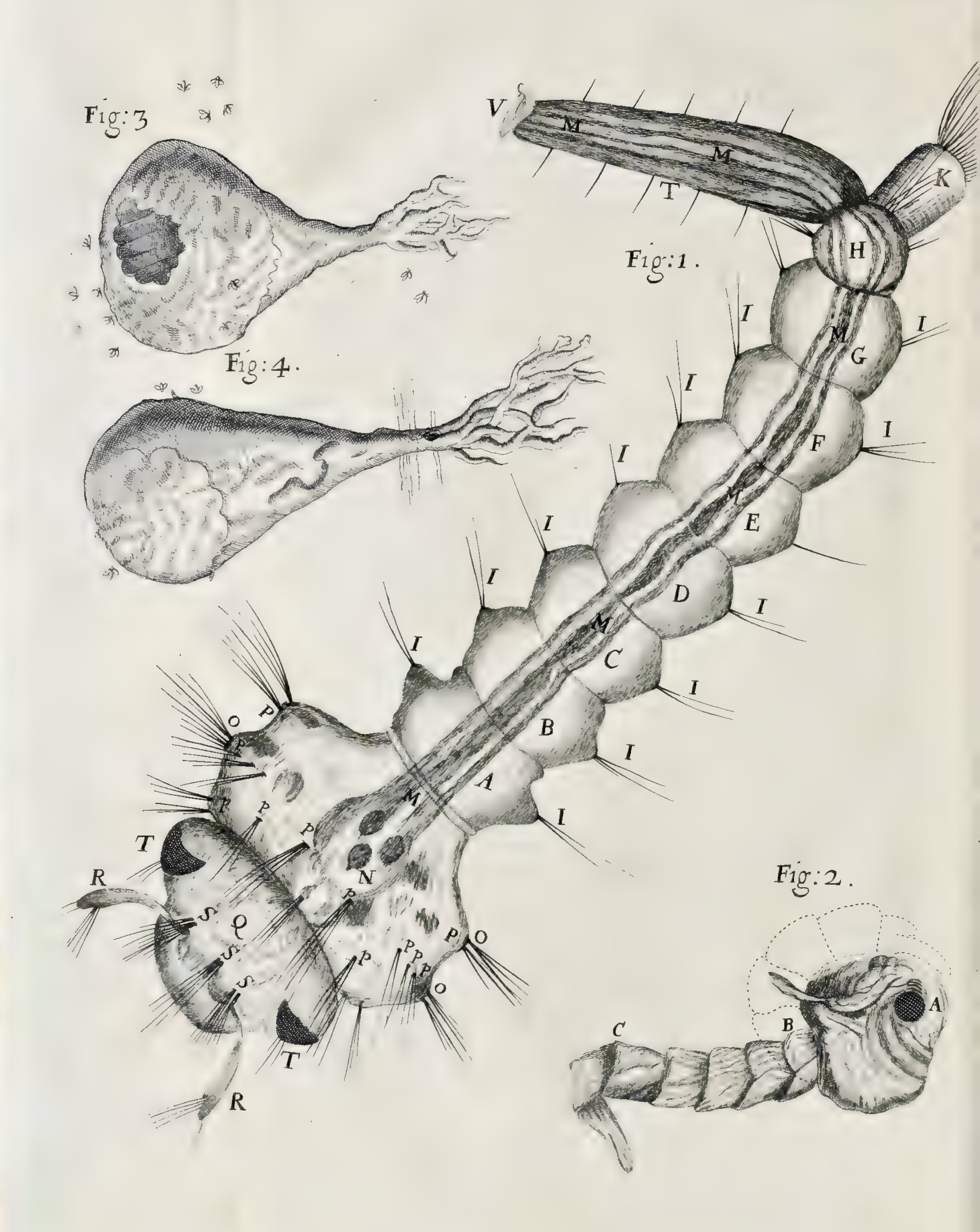
 of

of differing kinds which I may, perhaps, elſewhere endeavour more accurately to examine, and to ſhew of how great benefit the uſe of a *Microſcope* may be for the diſcovery of Nature's courſe in the operations perform'd in Animal bodies, by which we have the opportunity of obſerving her through theſe delicate and pellucid teguments of the bodies of Inſects acting according to her uſual courſe and way, undiſturbed, whereas, when we endeavour to pry into her ſecrets by breaking open the doors upon her, and diſſecting and mangling creatures whil'ſt there is life yet within them, we find her indeed at work, but put into ſuch diſorder by the violence offer'd, as it may eaſily be imagin'd,how differing a thing we ſhould find,if we could,as we can with a *Microſcope*,in theſe ſmaller creatures, quietly peep in at the windows, without frighting her out of her uſual byas.

The form of the whole creature, as it appear'd in the *Microſcope*, may, without troubling you with more deſcriptions, be plainly enough perceiv'd by the *Scheme*, the hinder part or belly conſiſting of eight ſeveral jointed parts, namely, A B C D E F G H, of the firſt *Figure*, from the midſt of each of which,on either ſide,iſſued out three or four ſmall briſles or hairs, I, I, I, I, I, the tail was divided into two parts of very differing make; one of them, namely, K, having many tufts of hair or briſles, which ſeem'd to ſerve both for the finns and tail, for the Oars and Ruder of this little creature, wherewith it was able, by friſking and bending its body nimbly to andfro,to move himſelf any whither,and to ſkull and ſteer himſelf as he pleas'd;the other part, L, ſeem'd to be,as 'twere,the ninth diviſion of his belly,and had many ſingle briſles on either ſide. From the end V, of which, through the whole belly, there was a kind of Gut of a darker colour, M M M, wherein, by certain *Periſtaltick* motions there was a kind of black ſubſtance mov'd upwards and downwards through it from the orbicular part of it, N,(which ſeem'd the *Ventricle*,or ſtomach)to the tail V,and ſo back again, which *periſtaltick* motion I have obſerv'd alſo in a Louſe, a Gnat, and ſeveral other kinds of tranſparent body'd Flies. The *Thorax* or cheſt of this creature O O O O, was thick and ſhort, and pretty tranſparent, for through it I could ſee the white heart (which is the colour alſo of the bloud in theſe, and moſt other Inſects) to beat, and ſeveral other kind of motions. It was beſtuck and adorn'd up and down with ſeveral tufts of briſles, ſuch as are pointed out by P, P, P, P, the head Q was likewiſe beſtuck with ſeveral of thoſe tufts, S S S; it was broad and ſhort, had two black eyes, T T, which I could not perceive at all pearl'd, as they afterwards appear'd, and two ſmall horns, R R, ſuch as I formerly deſcrib'd.

Both its motion and reſt is very ſtrange, and pleaſant, and differing from thoſe of moſt other creatures I have obſerv'd; for, where it ceaſes from moving its body, the tail of it ſeeming much lighter then the reſt of its body,and a little lighter then the water it ſwims in, preſently boys it up to the top of the water, where it hangs ſuſpended with the head always downward; and like our *Antipodes*, if they do by a friſk get below that ſuperficies, they preſently aſcend again unto it, if they ceaſe moving,




Fig: 1.
Fig: 2.
Fig: 3
Fig: 4.

moving, until they tread, as it were, under that ſuperficies with their tails; the hanging of theſe in this poſture, put me in mind of a certain creature I have ſeen in *London*, that was brought out of *America*, which would very firmly ſuſpend it ſelf by the tail, with the head downwards, and was ſaid to ſleep in that poſture, with her young ones in her falſe belly, which is a Purſe, provided by Nature for the production, nutrition, and preſervation of her young ones, which is deſcribed by *Piſo* in the 24. Chapter of the fifth Book of his Natural Hiſtory of *Braſil*.

The motion of it was with the tail forwards, drawing its ſelf backwards, by the friſking to and fro of that tuft which grew out of one of the ſtumps of its tail. It had another motion, which was more ſutable to that of other creatures, and that is, with the head forward; for by the moving of his chaps (if I may ſo call the parts of his mouth) it was able to move it ſelf downwards very gently towards the bottom, and did, as 'twere, eat up its way through the water.

But that which was moſt obſervable in this creature, was, its Metamorphoſis or change; for having kept ſeveral of theſe Animals in a Glaſs of Rain-water, in which they were produc'd, I found, after about a fortnight or three weeks keeping, that ſeveral of them flew away in Gnats, leaving their huſks behind them in the water floating under the ſurface, the place where theſe Animals were wont to reſide, whil'ſt they were inhabitants of the water: this made me more diligently to watch them, to ſee if I could find them at the time of their transformation; and not long after, I obſerv'd ſeveral of them to be changed into an unuſual ſhape, wholly differing from that they were of before, their head and body being grown much bigger and deeper, but not broader, and their belly, or hinder part ſmaller, and coyl'd, about this great body much of the faſhion repreſented by the prick'd line in the ſecond *Figure* of the 27. *Scheme*, the head and horns now ſwam uppermoſt, and the whole bulk of the body ſeem'd to be grown much lighter; for when by my frighting of it, it would by friſking out of its tail (in the manner expreſs'd in the Figure by B C) ſink it ſelf below the ſurface towards the bottom; the body would more ſwiftly re-aſcend, then when it was in its former ſhape.

I ſtill marked its progreſs from time to time, and found its body ſtill to grow bigger and bigger, Nature, as it were, fitting and accoutring it for the lighter Element, of which it was now going to be an inhabitant; for, by obſerving one of theſe with my *Microſcope*, I found the eyes of it to be altogether differing from what they ſeem'd before, appearing now all over pearl'd or knobb'd, like the eyes of Gnats. as is viſible in the ſecong *Figure* by A. At length, I ſaw part of this creature to ſwim above, and part beneath the ſurface of the water, below which though it would quickly plunge it ſelf if I by any means frighted it, and preſently re-aſcend into its former poſture; after a little longer expectation, I found that the head and body of a Gnat, began to appear and ſtand cleer above the ſurface, and by degrees it drew out its leggs, firſt the two formoſt, then the other, at length its whole body perfect and entire appear'd out of the huſk (which it left in the water) ſtanding on its leggs upon

the top of the water, and by degrees it began to move, and after flew about the Glaſs a perfect Gnat.

I have been the more particular, and large in the relation of the tranſformation of divers of theſe little Animals which I obſerv'd, becauſe I have not found that any Authour has obſerv'd the like; and becauſe the thing it ſelf is ſo ſtrange and heterogeneous from the uſual progreſs of other Animals, that I judge it may not onely be pleaſant, but very uſefull and neceſſary towards the compleating of Natural Hiſtory.

There is indeed in *Piſo*, a very odd Hiſtory, which this relation may make the more probable; and that is in the 2. Chapter of the 4. Book of his Natural Hiſtory of *Braſil*, where he ſays, *Porro præter tot documenta fertilitatis circa vegetabilia & ſenſitiva marina telluris æmula, accidit & illud, quod paucis à Paranambucenſi milliaribus, piſcatoris uncum citra intentionem contingat infigi vadis petroſis, & loco piſcis ſpongia, coralla, aliaſque arbuſculas marinas capi. Inter hæc inuſitatæ formæ prodit ſpongioſa arbuſcula, ſeſquipedis longitudinis, brevioribus radicibus, lapideis nitens vadis, & rupibus infixa, erigiturque in corpus ſpongioſum molle oblongum rotundum turbinatum: intus miris cancellis & alveis fabricatum, extus autem tenaci glutine inſtar Apum propolis undique veſtitum, oſtio ſatis patulo & profundo in ſummitate relicto, ſicut ex altera iconum probe depicta videre licet* (ſee the third and fourth Figures of the 27. *Scheme.*) *Ita ut Apiarium marinum vere dixeris; primo enim intuitu è Mare ad Terram delatum, vermiculis ſcatebat cæruleis parvis, qui mox à calore ſolis in Muſcas, vel Apes potius, eaſq; exiguas & nigras tranſformebantur, circumvolanteſque evaneſcebant, ita ut de eorum mellificatione nihil certi conſpici datum fuerit, cum tamen ceroſa materia propolis Apumque cellæ manifeſte apparerent, atque ipſa mellis qualiſcunque ſubſtantia proculdubio urinatoribus patebit, ubi curioſius inquiſiverint hæc apiaria, eaque in natali ſolo & ſalo diverſis temporibus penitius luſtrarint.*

Which Hiſtory contains things ſufficiently ſtrange to be conſider'd, as whether the huſk were a Plant, growing at the bottom of the Sea before, of it ſelf, out of whoſe putrifaction might be generated theſe ſtrange kind of Magots; or whether the ſeed of certain Bees, ſinking to the bottom, might there naturally form it ſelf that vegetable hive, and take root; or, whether it might not be placed there by ſome diving Fly; or, whether it might not be ſome peculiar propriety of that Plant, whereby it might ripen or form its vegetable juice into an Animal ſubſtance; or, whether it may not be of the nature of a Sponge, or rather a Sponge of the nature of this, according to ſome of thoſe relations and conjectures I formerly made of that body, is a matter very difficult to be determined. But indeed, in this deſcription, the Excellent *Piſo* has not been ſufficiently particular in the ſetting down the whole proceſs, as it were to be wiſh'd: There are indeed very odd progreſſes in the production of ſeveral kinds of Inſects, which are not leſs inſtructive then pleaſant, ſeveral of which, the diligent *Goedartius* has carefully obſerv'd and recorded, but among all his Obſervations, he has none like this, though that of the *Hemerobius* be ſomewhat of this kind, which is added as an Appendix by *Johannes Mey.*

I have

I have, for my own particular, beſides ſeveral of thoſe mention'd by him, obſerv'd divers other circumſtances, perhaps, not much taken notice of, though very common, which do indeed afford us a very *coercive* argument to admire the goodneſs and providence of the infinitely wiſe Creator in his moſt excellent contrivances and diſpenſations. I have obſerv'd, at ſeveral times of the Summer, that many of the leaves of divers Plants have been ſpotted, or, as it were ſcabbed, and looking on the underſides of thoſe of them that have been but a litte irregular, I have perceiv'd them to be ſprinkled with divers ſorts of little Eggs, which letting alone, I have found by degrees to grow bigger, and become little Worms with leggs, but ſtill to keep their former places, and thoſe places of the leaves, of their own accords, to be grown very protuberant upwards, and very hollow, and arched underneath, whereby thoſe young creatures are, as it were, ſhelter'd and houſed from external injury; divers leaves I have obſerv'd to grow and ſwell ſo farr, as at length perfectly to incloſe the Animal, which, by other obſervations I have made, I gheſs to contain it, and become, as it were a womb to it, ſo long, till it be fit and prepar'd to be tranſlated into another ſtate, at what time, like (what they ſay of) Vipers, they gnaw their way through the womb that bred them; divers of theſe kinds I have met with upon Gooſberry leaves, Roſe-tree leaves, Willow leaves, and many other kinds.

There are often to be found upon Roſe-trees and Brier buſhes, little red tufts, which are certain knobs or excreſcencies, growing out from the Rind, or barks of thoſe kinds of Plants, they are cover'd with ſtrange kinds of threads or red hairs, which feel very ſoft, and look not unpleaſantly. In moſt of theſe, if it has no hole in it, you ſhall find certain little Worms, which I ſuppoſe to be the cauſes of their production; for when that Worm has eat its way through, they, having performed what they were deſign'd by Nature to do, by degrees die and wither away.

Now, the manner of their production, I ſuppoſe to be thus; that the Al-wiſe Creator has as well implanted in every creature a faculty of knowing what place is convenient for the hatching, nutrition, and preſervation of their Eggs and of-ſprings, whereby they are ſtimulated and directed to convenient places, which becom, as 'twere the wombs that perform thoſe offices: As he has alſo ſuited and adapted a property to thoſe places wherby they grow and incloſe thoſe ſeeds, and having incloſed them, provide a convenient nouriſhment for them, but as ſoon as they have done the office of a womb, they die and wither.

The progreſs of incloſure I have often obſerv'd in leaves, which in thoſe places where thoſe ſeeds have been caſt, have by degrees ſwell'd and inclos'd them, ſo perfectly round, as not to leave any perceptible paſſage out.

From this ſame cauſe, I ſuppoſe that Galls, Oak-apples, and ſeveral other productions of that kind, upon the branches and leaves of Trees, have their original; for if you open any of them, when almoſt ripe, you ſhall find a little Worm in them. Thus, if you open never ſo many dry Galls, you ſhall find either a hole whereby the Worm has eat its paſſage out,

out, or if you find no paſſage, you may,by breaking or cutting the Gall, find in the middle of it a ſmall cavity, and in it a ſmall body, which does plainly enough yet retain a ſhape, to manifeſt it once to have been a Worm, though it dy'd by a too early ſeparation from the Oak on which it grew,its navel-ſtring,as 'twere,being broken off from the leaf or branch by which the Globular body that invelop'd it, received its nouriſhment from the Oak.

And indeed,if we conſider the great care of the Creator in the diſpenſations of his providences for the propagation and increaſe of the race,not onely of all kind of Animals, but even of Vegetables, we cannot chuſe but admire and adore him for his Excellencies, but we ſhall leave off to admire the creature, or to wonder at the ſtrange kind of acting in ſeveral Animals, which ſeem to ſavour ſo much of reaſon; it ſeeming to me moſt manifeſt,that thoſe are but actings according to their ſtructures, and ſuch operations as ſuch bodies, ſo compos'd, muſt neceſſarily, when there are ſuch and ſuch circumſtances concurring, perform: thus,whenwe find Flies ſwarming,about any piece of fleſh that does begin a little to ferment;Butterflies about Colworts,and ſeveral other leaves,which will ſerve to hatch and nouriſh their young; Gnats, and ſeveral other Flies about the Waters, and mariſhy places,or any other creatures, ſeeking and placing their Seeds in convenient repoſitories, we may, if we attentively conſider and examine it, find that there are circumſtances ſufficient,upon the ſuppoſals of the excellent contrivance of their machine,to excite and force them to act after ſuch or ſuch a manner; thoſe ſteams that riſe from theſe ſeveral places may, perhaps, ſet ſeveral parts of theſe little Animals at work,even as in the contrivance of killing a Fox or Wolf with a Gun, the moving of a ſtring, is the death of the Animal; for the Beaſt, by moving the fleſh that is laid to entrap him, pulls the ſtring which moves the trigger, and that lets go the Cock which on the ſteel ſtrikes certain ſparks of fire which kindle the powder in the pann, and that preſently flies into the barrel, where the powder catching fire rarifies and drives out the bullet which kills the Animal; in all which actions, there is nothing of intention or ratiocination to be aſcrib'd either to the Animal or Engine, but all to the ingenioufneſs of the contriver.

But to return to the more immediate conſideration of our Gnat: We have in it an Inſtance, not uſual or common,of a very ſtange *amphibious* creature, that being a creature that inhabits the Air, does yet produce a creature, that for ſome time lives in the water as a Fiſh, though afterward (which is as ſtrange) it becomes an inhabitant of the Air, like its Sire,in the form of a Fly. And this, me thinks, does prompt me to propoſe certain conjectures, as Queries, having not yet had ſufficient opportunity and leiſure to anſwer them my ſelf from my own Experiments or Obſervations.

And the firſt is, Whether all thoſe things that we ſuppoſe to be bred from corruption and putrifaction, may not be rationally ſuppos'd to have their origination as natural as theſe Gnats, who, 'tis very probable, were firſt dropt into this Water, in the form of Eggs. Thoſe Seeds or Eggs

Eggs muſt certainly be very ſmall, which ſo ſmall a creature as a Gnat yields, and therefore we need not wonder that we find not the Eggs themſelves, ſome of the younger of them, which I have obſerv'd, having not exceeded a tenth part of the bulk they have afterwards come to; and next, I have obſerved ſome of thoſe little ones which muſt have been generated after the Water was incloſed in the Bottle, and therefore moſt probably from Eggs, whereas thoſe creatures have been ſuppos'd to be bred of the corruption of the Water, there being not formerly known any probable way how they ſhould be generated.

A ſecond is, whether theſe Eggs are immediately dropt into the Water by the Gnats themſelves, or, mediately, are brought down by the falling rain; for it ſeems not very improbable, but that thoſe ſmall ſeeds of Gnats may (being, perhaps, of ſo light a nature, and having ſo great a proportion of ſurface to ſo ſmall a bulk of body) be ejected into the Air, and ſo, perhaps, carried for a good while too and fro in it, till by the drops of Rain it be waſh'd out of it.

A third is, whether multitudes of thoſe other little creatures that are found to inhabit the Water for ſome time, do not, at certain times, take wing and fly into the Air, others dive and hide themſelves in the Earth, and ſo contribute to the increaſe both of the one and the other Element.

Poſtſcript.

A good while ſince the writing of this Deſcription, I was preſented by Doctor *Peter Ball*, an ingenious Member of the *Royal Society*, with a little Paper of Nuts, which he told me was ſent him from a Brother of his out of the Countrey, from *Mamhead* in *Devonſhire*, ſome of them were looſe, having been, as I ſuppoſe, broken off, others were ſtill growing faſt on upon the ſides of a ſtick, which ſeem'd by the bark, pliableneſs of it, and by certain ſtrings that grew out of it, to be ſome piece of the root of a Tree; they were all of them dry'd, and a little ſhrivell'd, others more round, of a brown colour; their ſhape was much like a Figg, but very much ſmaller, ſome being about the bigneſs of a Bay-berry, others, and the biggeſt, of a Hazel-Nut. Some of theſe that had no hole in them, I carefully opened with my Knife, and found in them a good large round white Maggot, almoſt as bigg as a ſmall Pea, which ſeem'd ſhap'd like other Maggots, but ſhorter. I could not find them to move, though I gheſs'd them to be alive, becauſe upon pricking them with a Pinn, there would iſſue out a great deal of white *mucous* matter, which ſeem'd to be from a voluntary contraction of their ſkin; their huſk or matrix conſiſted of three Coats, like the barks of Trees, the outermoſt being more rough and ſpongie, and the thickeſt, the middlemoſt more cloſe, hard, white, and thin, the innermoſt very thin, ſeeming almoſt like the ſkin within an Egg's ſhell. The two outermoſt had root in the branch or ſtick, but the innermoſt had no ſtem or proceſs, but was onely a ſkin that cover'd the cavity of the Nut. All the Nuts that had no holes eaten in them, I found to contain theſe Maggots, but all that had holes, I found empty, the Maggots,

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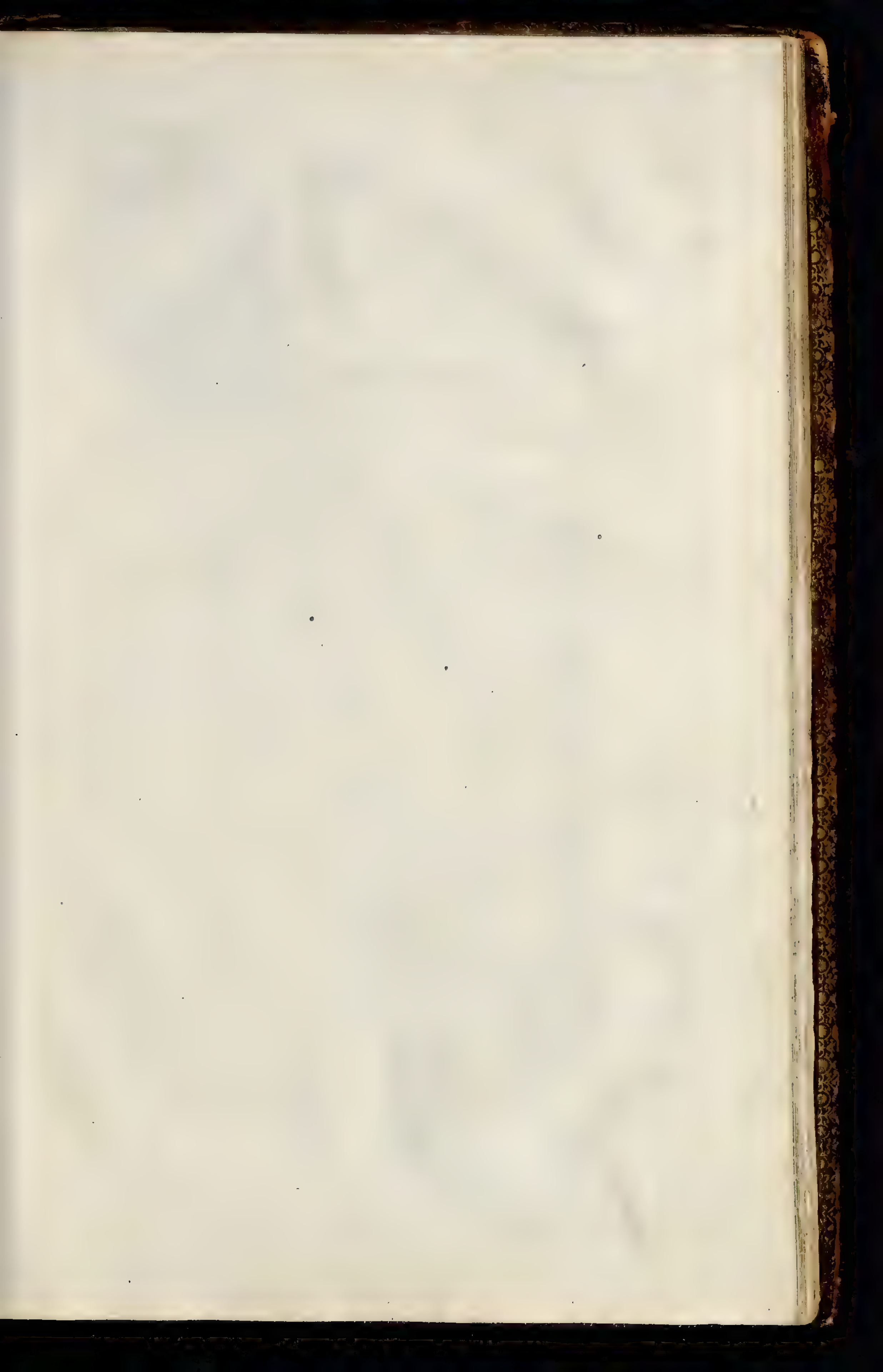
it ſeems, having eaten their way through, taken wings and flown away, as this following account (which I receiv'd in writing from the ſame perſon, as it was ſent him by his Brother) manifeſts. *In a mooriſh black Peaty mould, with ſome ſmall veins of whitiſh yellow Sands, upon occaſion of digging a hole two or three foot deep, at the head of a Pond or Pool, to ſet a Tree in, at that depth, were found, about the end of* October 1663. *in thoſe very veins of Sand, thoſe Buttons or Nuts, ſticking to a little looſe ſtick, that is, not belonging to any live Tree, and ſome of them alſo free by themſelves.*

Four or five of which being then open'd, ſome were found to contvin live Inſects come to perfection, moſt like to flying Ants, *if not the ſame; in others, Inſects, yet imperfect, having but the head and wings form'd, the reſt remaining a ſoft white pulpy ſubſtance.*

Now, as this furniſhes us with one odd Hiſtory more, very agreeable to what I before hinted, ſo I doubt not, but were men diligent obſervers, they might meet with multitudes of the ſame kind, both in the Earth and in the Water, and in the Air, on Trees, Plants, and other Vegetables, all places and things being, as it were, *animarum plena.* And I have often, with wonder and pleaſure, in the Spring and Summer-time, look'd cloſe to, and diligently on, common Garden mould, and in a very ſmall parcel of it, found ſuch multitudes and diverſities of little *reptiles*, ſome in huſks, others onely creepers, many wing'd, and ready for the Air; divers huſks or habitations left behind empty. Now, if the Earth of our cold Climate be ſo fertile of animate bodies, what may we think of the fat Earth of hotter Climates? Certainly, the Sun may there, by its activity, cauſe as great a parcel of Earth to fly on wings in the Air, as it does of Water in ſteams and vapours. And what ſwarms muſt we ſuppoſe to be ſent out of thoſe plentifull inundations of water which are poured down by the ſluces of Rain in ſuch vaſt quantities? So that we need not much wonder at thoſe innumerable clouds of Locuſts with which *Africa*, and other hot countries are ſo peſtred, ſince in thoſe places are found all the convenient cauſes of their production, namely, genitors, or Parents, concurrent receptacles or matrixes, and a ſufficient degree of natural heat and moiſture.

I was going to annex a little draught of the Figure of thoſe Nuts ſent out of *Devonſhire*, but chancing to examine Mr. *Parkinſon's* Herbal for ſomething elſe, and particularly about Galls and Oak-apples, I found among no leſs then 24. ſeveral kinds of excreſcencies of the Oak, which I doubt not, but upon examination, will be all found to be the *matrixes* of ſo many ſeveral kinds of Inſects; I having obſerv'd many of them my ſelf to be ſo, among 24. ſeveral kinds, I ſay, I found one deſcribed and Figur'd directly like that which I had by me, the *Scheme* is there to be ſeen, the deſcription, becauſe but ſhort, I have here adjoin'd *Theatri Botanci trib.*16. *Chap.* 2. *There groweth at the roots of old Oaks in the Spring-time, and ſometimes alſo in the very heat of Summer, a peculiar kind of Muſhrom or Excreſcence, call'd* Uva Quercina, *ſwelling out of the Earth, many growing one cloſe unto another, of the faſhion of a Grape, and therefore took the name, the* Oak-Grape, *and is of a Purpliſh colour on the outſide,*

and



Schem: XXVIII.

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and white within like Milk, and in the end of Summer becometh hard and woody. Whether this be the very ſame kind, I cannot affirm, but both the Picture and Deſcription come very neer to that I have, but that he ſeems not to take notice of the hollowneſs or Worm, for which 'tis moſt obſervable. And therefore 'tis very likely, if men did but take notice, they might find very many differing Species of theſe Nuts, *Ovaries*, or *Matrixes*, and all of them to have much the ſame deſignation and office. And I have very lately found ſeveral kinds of Excreſcencies on Trees and Shrubs, which having endured the Winter, upon opening them, I found moſt of them to contain little Worms, but dead, thoſe things that contain'd them being wither'd and dry.

Obſerv. XLIV. *Of the tufted or Bruſh-horn'd* Gnat.

THis little creature was one of thoſe multitudes that fill our *Engliſh* air all the time that warm weather laſts, and is exactly of the ſhape of that I obſerv'd to be generated and hatch'd out of thoſe little Inſects that wriggle up and down in Rain-water. But,though many were of this form, yet I obſerv'd others to be of quite other kinds; nor were all of this or the other kind generated out of Water Inſects; for whereas I obſerv'd that thoſe that proceeded from thoſe Inſects were at their full growth, I have alſo found multitudes of the ſame ſhape,but much ſmaller and tenderer ſeeming to be very young ones, creep up and down upon the leaves of Trees, and flying up and down in ſmall cluſters, in places very remote from water; and this Spring, I obſerv'd one day, when the Wind was very calm, and the afternoon very fair, and pretty warm, though it had for a long time been very cold weather, and the wind continued ſtill in the Eaſt, ſeveral ſmall ſwarms of them playing to and fro in little clouds in the Sun, each of which were not a tenth part of the bigneſs of one of theſe I here have delineated, though very much of the ſame ſhape, which makes me gheſs, that each of theſe ſwarms might be the of-ſpring of one onely Gnat, which had been hoorded up in ſome ſafe repoſitory all this Winter by ſome provident Parent, and were now, by the warmth of the Spring-air, hatch'd into little Flies.

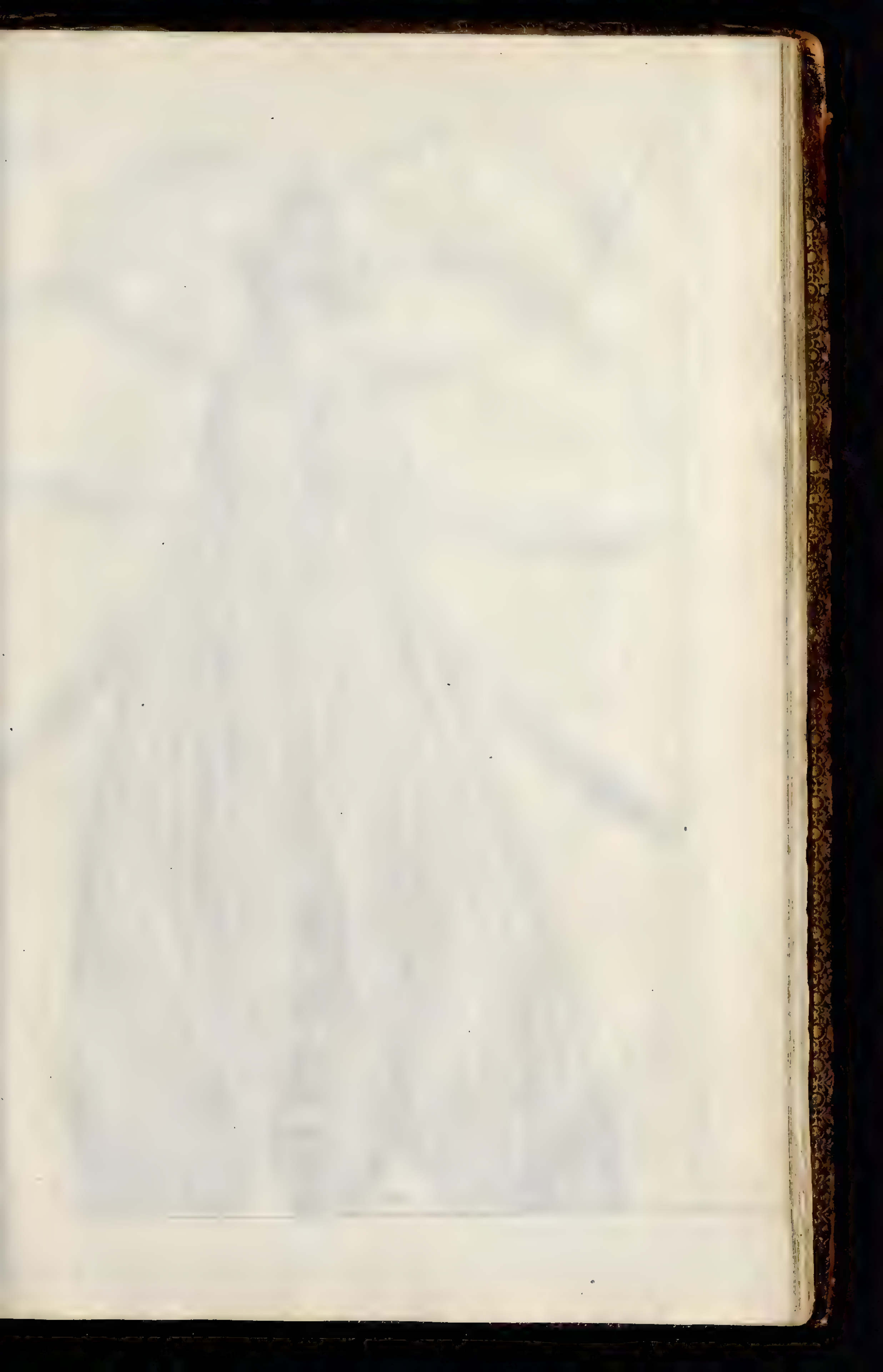
And indeed, ſo various, and ſeemingly irregular are the generations or productions of Inſects, that he that ſhall carefully and diligently obſerve the ſeveral methods of Nature therein, will have infinitely cauſe further to admire the wiſdom and providence of the Creator; for not onely the ſame kind of creature may be produc'd from ſeveral kinds of ways, but the very ſame creature may produce ſeveral kinds: For,as divers Watches may be made out of ſeveral materials, which may yet have all the ſame appearance,and move after the ſame manner,that is,ſhew the hour equally true, the one as the other, and out of the ſame kind of matter, like Watches,may be wrought differing ways; and,as one and the ſame Watch

may, by being diversly agitated, or mov'd, by this or that agent, or after this or that manner, produce a quite contrary effect: So may it be with these most curious Engines of Insect's bodies; the All-wise God of Nature, may have so ordered and disposed the little *Automatons*, that when nourished, acted, or enlivened by this cause, they produce one kind of effect, or animate shape, when by another they act quite another way, and another Animal is produc'd. So may he so order several materials, as to make them, by several kinds of methods, produce similar *Automatons*.

But to come to the Description of this Insect, as it appears through a *Microscope*, of which a representation is made in the 28. *Scheme*. Its head A, is exceeding small, in proportion to its body, consisting of two clusters of pearl d eyes B B, on each side of its head, whose pearls or eye-balls are curiously rang'd like those of other Flies; between these, in the forehead of it, there are plac'd upon two small black balls, C C, two long jointed horns, tapering towards the top, much resembling the long horns of Lobsters, each of whose stems or quills, D D, were brisled or brushed with multitudes of small stiff hairs, issuing out every way from the several joints, like the strings or sproutings of the herb *Horse-tail*, which is oft observ'd to grow among Corn, and for the whole shape, it does very much resemble those *brushy Vegetables*; besides these, there are two other jointed and brisled horns, or feelers, E E, in the forepart of the head, and a *proboscis*, F, underneath, which in some Gnats are very long, streight hollow pipes, by which these creatures are able to drill and penetrate the skin, and thence, through those pipes suck so much bloud as to stuff their bellies so full till they be ready to burst.

This small head, with its appurtenances, is fastned on by a short neck, G, to the middle of the *thorax*, which is large, and seems cased with a strong black shel, H I K, out of the under part of which, issue six long and slender legs, L L L L L L, shap'd just like the legs of Flies, but spun or drawn out longer and slenderer, which could not be express'd in the Figure, because of their great length; and from the upper part, two oblong, but slender transparent wings, M M, shaped somewhat like those of a Fly, underneath each of which, as I have observ'd also in divers sorts of Flies, and other kinds of Gnats, was placed a small body, N, much resembling a drop of some transparent glutinous substance, hardned or cool'd, as it was almost ready to fall, for it has a round knob at the end, which by degrees grows slenderer into a small stem, and neer the insertion under the wing, this stem again grows bigger; these little *Pendulums*, as I may so call them, the litle creature vibrates to and fro very quick when it moves its wings, and I have sometimes observ'd it to move them also, whil'st the wing lay still, but always their motion seem'd to further the motion of the wing ready to follow; of what use they are, as to the moving of the wing, or otherwise, I have not now time to examine.

Its belly was large, as it is usually in all Insects, and extended into nine lengths or partitions, each of which was cover'd with round armed rings or shells; six of which, O P Q R S T were transparent, and divers kinds of *Peristaltick* motions might be very easily perceiv'd, whil'st the Animal was




Schem. XX

Was alive, but especially a small cleer white part V, seemed to beat like the heart of a larger Animal. The last three divisios, W X Y, were cover'd with black and opacous shells. To conclude, take this creature altogether, and for beauty and curious contrivances, it may be compared with the largest Animal upon the Earth. Nor doth the Alwise Creator seem to have shewn less care and providence in the fabrick of it, then in those which seem most considerable.

Observ. XLV. *Of the great Belly'd* Gnat *or female* Gnat.

THe second Gnat, delineated in the twenty ninth *Scheme*, is of a very differing shape from the former; but yet of this sort also, I found several of the Gnats, that were generated out of the Water Insect: the wings of this, were much larger then those of the other, and the belly much bigger, shorter and of an other shape; and, from several particulars, I ghest it to be the Female Gnat, and the former to be the Male.

The *thorax* of this, was much like that of the other, having a very strong and ridged back-piece, which went also on either side of its leggs; about the wings there were several joynted pieces of Armor, which seem'd curiously and conveniently contriv'd, for the promoting and strengthning the motion of the wings: its head was much differing from the other, being much bigger and neater shap'd, and the horns that grew out between his eyes on two little balls, were of a very differing shape from the tufts of the other Gnat, these having but a few knots or joynts, and each of those but a few, and those short and strong, brisles. The formost horns or feelers, were like those of the former Gnat.

One of these Gnats I have suffer'd to pierce the skin of my hand, with its *proboscis*, and thence to draw out as much blood as to fill its belly as full as it could hold, making it appear very red and transparent; and this without any further pain, then whilst it was sinking in its *proboscis*, as it is also in the stinging of Fleas: a good argument, that these creatures do not wound the skin, and suck the blood out of enmity and revenge, but for meer necessity, and to satisfy their hunger. By what means this creature is able to suck, we shall shew in another place.

Observ. XLVI. *Of the white featherwing'd* Moth *or* Tinea Argentea.

THis white long wing'd Moth, which is delineated in the 30. *Scheme*, afforded a lovely object both to the naked Eye, and through a *Microscope*: to the Eye it appear'd a small Milk white Fly with four white

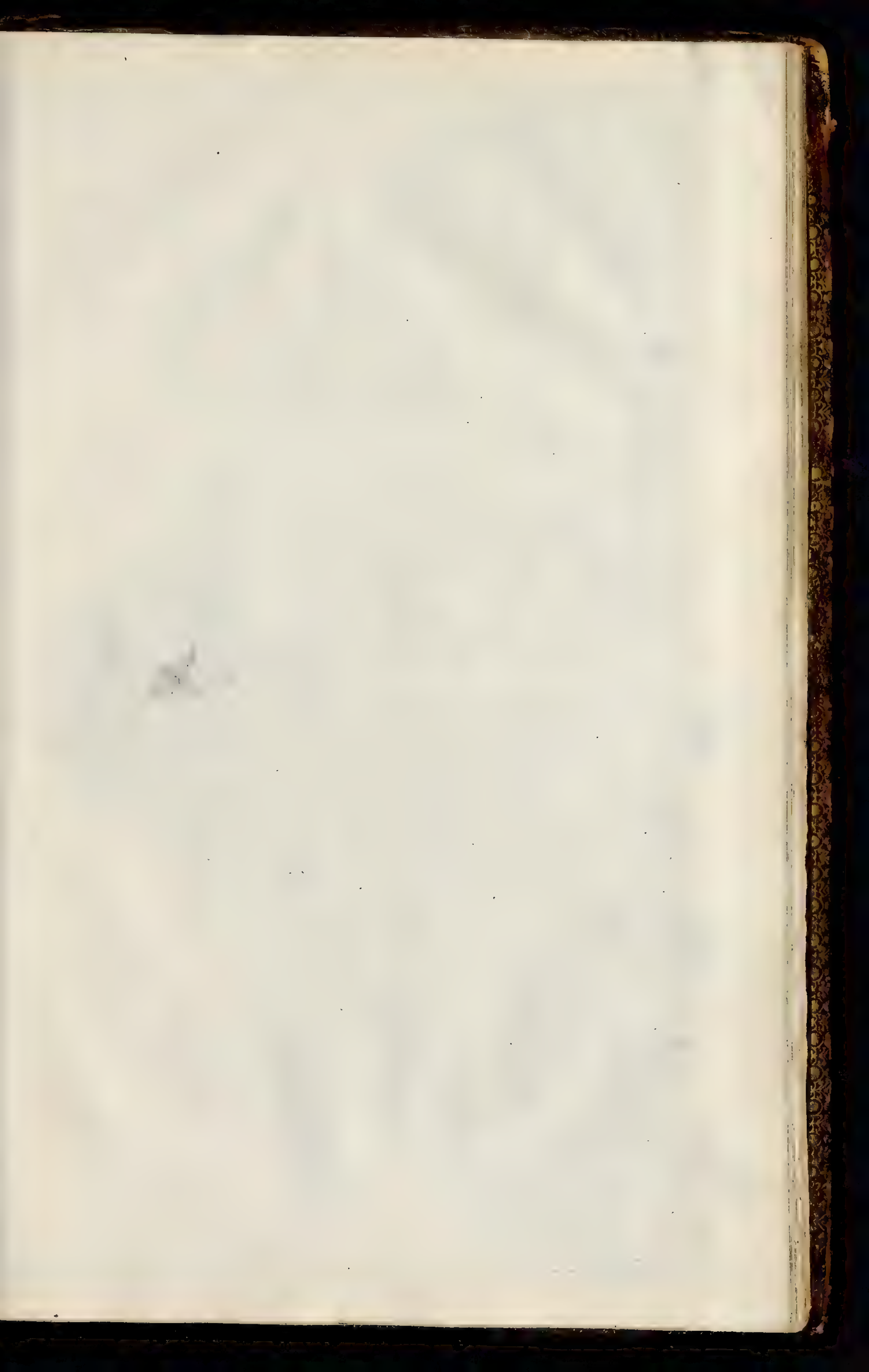
Wings, the two formoſt ſomewhat longer then the two hindermoſt, and the two ſhorter about half an Inch long, each of which four Wings ſeem'd to conſiſt of two ſmall long Feathers, very curiouſly tufted, or haired on each ſide, with purely white, and exceedingly fine and ſmall Haires, proportion'd to the ſtalks or ſtems, out of which they grew, much like the tufts of a long wing-feather of ſome Bird, and their ſtalks or ſtems were, like thoſe, bended backwards and downwards, as may be plainly ſeen by the draughts of them in the Figure.

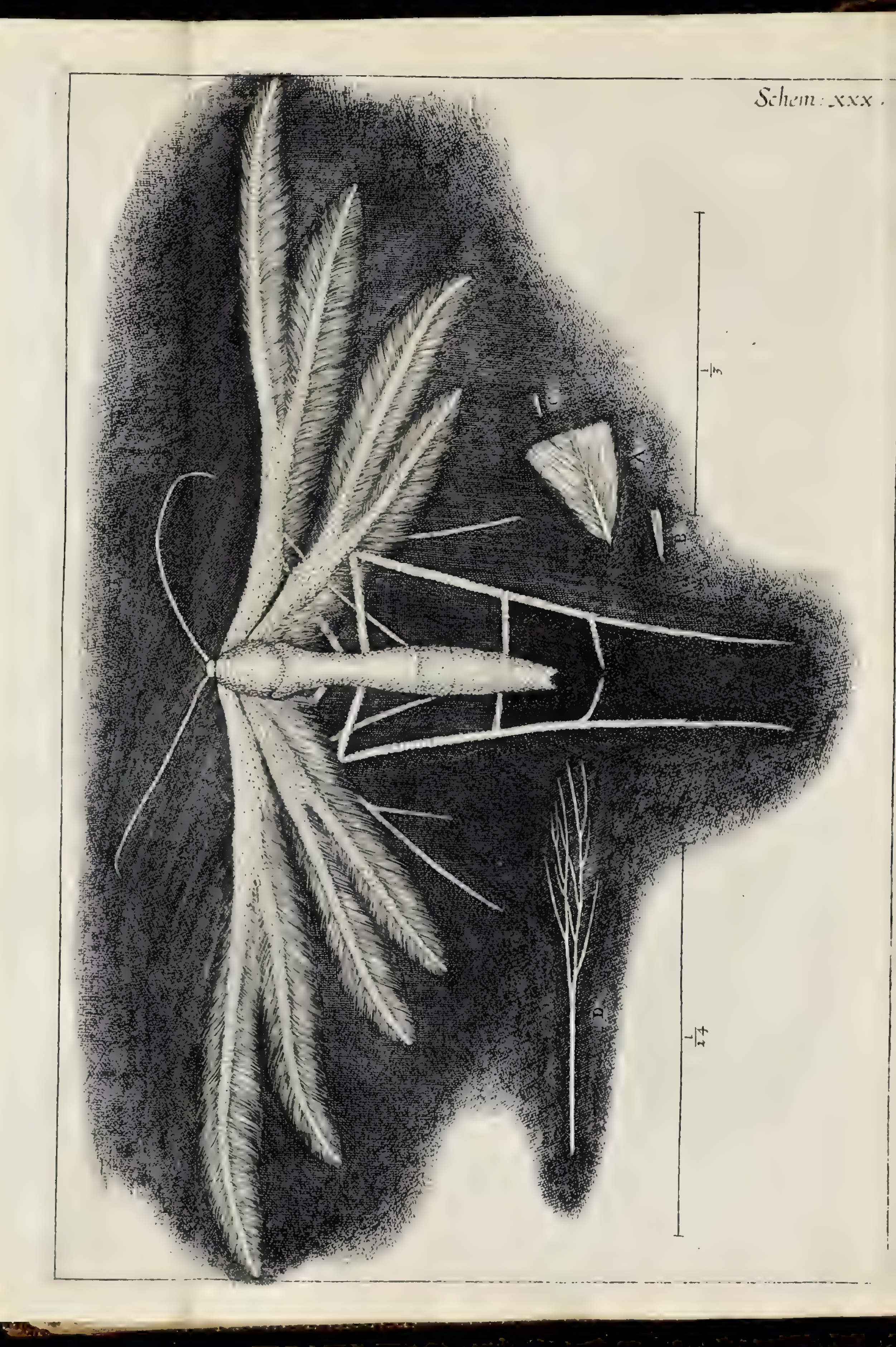
Obſerving one of theſe in my *Microſcope*, I found, in the firſt place, that all the Body, Legs, Horns and the Stalks of the Wings, were covered over with various kinds of curious white Feathers, which did, with handling or touching, eaſily rubb off and fly about, in ſo much that looking on my Fingers, with which I had handled this Moth, and perceiving on them little white ſpecks, I found by my *Microſcope*, that they were ſeveral of the ſmall Feathers of this little creature, that ſtuck up and down in the *rugoſities* of my Skin.

Next, I found that underneath theſe Feathers, the pretty Inſect was covered all over with a cruſted Shell, like other of thoſe Animals, but with one much thinner and tenderer.

Thirdly, I found, as in Birds alſo is notable, it had differing and appropriate kinds of Feathers, that covered ſeveral parts of its body.

Fourthly, ſurveying the parts of its body, with a more accurate and better Magnifying *Microſcope*, I found that the tufts or haires of its Wings were nothing elſe but a congeries, or thick ſet cluſter of ſmall *vimina* or twiggs, reſembling a ſmall twigg of Birch, ſtript or whit[illegible] with which Bruſhes are uſually made, to beat out or bruſh off the duſt from Cloth and Hangings. Every one of the twiggs or branches that compoſed the Bruſh of the Feathers, appeared in this bigger Magnifying Glaſs (of which E F which repreſents $\frac{1}{24}$ part of an Inch, is the ſcale, as G is of the leſſer, which is only $\frac{1}{3}$) like the figure D. The Feathers alſo that covered a part of his Body, and were interſperſed among the bruſh of his Wings, I found, in the bigger Magnifying Glaſs, of the ſhape A, conſiſting of a ſtalk or ſtem in the middle, and a ſeeming tuftedneſs or bruſhy part on each ſide. The Feathers that cover'd moſt part of his Body and the ſtalk of his wings, were, in the ſame *Microſcope*, much of the figure B, appearing of the ſhape of a ſmall Feather, and ſeemed tufted: thoſe which covered the Horns and ſmall parts of the Leggs, through the ſame *Microſcope*, appear'd of the ſhape C. Whether the tufts of any or all of theſe ſmall Feathers, conſiſted of ſuch component particles as the Feathers of Birds, I much doubt, becauſe I find that Nature does not alwaies keep, or operate after the ſame method, in ſmaller and bigger creatures. And of this, we have particular Inſtances in the Wings of ſeveral creatures. For whereas, in Birds of all kinds, it compoſes each of the Feathers of which its Wing conſiſts, of ſuch an exceeding curious and moſt admirable and ſtupendious texture, as I elſe where ſhew, in the Obſervations on a Feather; we find it to alter its method quite, in the fabrick of the Wings of theſe minute creatures, compoſing ſome of thin extended membranes




Schem: xxx.
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or ſkins, ſuch as the Wings of Dragon-flys; in others, thoſe ſkins are all over-grown, or pretty thick beſtuck, with ſhort briſles, as in Fleſh-flies; in others, thoſe filmes are covered, both on the upper and under ſide, with ſmall Feathers, plac'd almoſt like the tyles on a Houſe, and are curiouſly rang'd and adorn'd with moſt lively colours; as is obſervable in Butter-flies, and ſeveral kinds of Moths; In others, inſtead of their films, Nature has provided nothing, but a matter of half a ſcore ſtalks (if I well remember the number; for I have not lately met with any of theſe flys, and did not, when I firſt obſerv'd them, take ſufficient notice of divers particulars) and each of theſe ſtalks, with a few ſingle branchings on each ſide, reſembling much the branched back-bone of a Herring or the like Fiſh, or a thin hair'd Peacocks feather, the top or the eye being broken off. With a few of theſe on either ſide (which it was able to ſhut up or expand at pleaſure, much like a Fann, or rather like the poſture of the feathers in a wing, which ly all one under another, when ſhut, and by the ſide of each other, when expanded) this pretty little grey Moth (for ſuch was the creature I obſerv'd, thus wing'd) could very nimbly, and as it ſeem'd very eaſily move its *corpuſcle*, through the Air, from place to place. Other Inſects have their wings cas'd, or cover'd over, with certain hollow ſhells, ſhap'd almoſt like thoſe hollow Trayes, in which Butchers carry meat, whoſe hollow ſides being turn'd downwards, do not only ſecure their folded wings from injury of the earth, in which moſt of thoſe creatures reſide, but whilſt they fly, ſerves as a help to ſuſtain and bear them up. And theſe are obſervable in *Scarabees* and a multitude of other terreſtrial *cruſtaceous* Inſects; in which we may yet further obſerve a particular providence of Nature.

Now in all theſe kinds of wings, we obſerve this particular, as a thing moſt worthy remark; that where ever a wing conſiſts of diſcontinued parts, the Pores or *interſtitia* between thoſe parts are very ſeldom, either much bigger, or much ſmaller, then theſe which we here find between the particles of theſe bruſhes, ſo that it ſhould ſeem to intimate, that the parts of the Air are ſuch, that they will not eaſily or readily, if at all, paſs through theſe Pores, ſo that they ſeem to be ſtrainers fine enough to hinder the particles of the Air (whether hinder'd by their bulk, or by their *agitation*, *circulation*, *rotation* or *undulation*, I ſhall not here determine) from getting through them, and, by that means, ſerve the Animal as well, if not better, then if they were little films. I ſay, if not better, becauſe I have obſerv'd that all thoſe creatures, that have film'd wings, move them aboundantly quicker and more ſtrongly, ſuch as all kind of Flies and *Scarabees* and Batts, then ſuch as have their wings covered with feathers, as Butter-flies and Birds, or twiggs, as Moths, which have each of them a much ſlower motion of their wings; That little ruggedneſs perhaps of their wings helping them ſomewhat, by taking better hold of the parts of the Air, or not ſuffering them ſo eaſily to paſs by, any other way then one.

But what ever be the reaſon of it, 'tis moſt evident, that the ſmooth wing'd Inſects have the ſtrongeſt Muſcles or movent parts of their wings, and the other much weaker; and this very Inſect, we are now deſcribing,

had

had a very ſmall *thorax* or middle part of his body, if compar'd to the length and number of his wings; which therefore, as he mov'd them very ſlowly,ſo muſt he move them very weakly. And this laſt propriety do we find ſomewhat obſerv'd alſo in bigger kind of Flying creatures,Birds; ſo that we ſee that the Wiſdom and Providence of the All-wiſe Creator, is not leſs ſhewn in theſe ſmall deſpicable creatures, Flies and Moths, which we have branded with a name of ignominy, calling them Vermine, then in thoſe greater and more remakable animate bodies, Birds.

I cannot here ſtand to add any thing about the nature of flying, though, perhaps, on another occaſion, I may ſay ſomething on that ſubject, it being ſuch as may deſerve a much more accurate examination and ſcrutiny then it has hitherto met with; For to me there ſeems nothing wanting to make a man able to fly, but what may be eaſily enough ſupply'd from the Mechanicks hitherto known, ſave onely the want of ſtrength, which the Muſcles of a man ſeem utterly uncapable of, by reaſon of their ſmalneſs and texture, but how even ſtrength alſo may be mechanically made, an artificial Muſcle ſo contriv'd,that thereby a man ſhall be able to exert what ſtrength he pleaſes, and to regulate it alſo to his own mind, I may elſewhere endeavour to manifeſt.

Obſerv. XLVII. *Of the* Shepherd Spider, *or long legg'd* Spider.

THe Carter,Shepherd Spider,or long-legg'd Spider,has, for two particularities, very few ſimilar creatures that I have met with; the firſt, which is diſcoverable onely by the *Microſcope*, and is in the firſt and ſecond *Figures* of the 31. *Scheme*, plainly deſcrib'd, is the curious contrivance of his eyes, of which (differing from moſt other Spiders) he has onely two, and thoſe plac'd upon the top of a ſmall pillar or hillock,riſing out of the middle of the top of its back, or rather the crown of its head, for they were fix'd on the very top of this pillar (which is about the heighth of one of the tranſverſe Diameters of the eye, and look'd on in another poſture,appear'd much of the ſhape, B C D) The two eyes, B B, were placedback to back, with the tranſparent parts,or the pupils, looking towards either ſide, but ſomewhat more forward then backwards. C was the column or neck on which they ſtood, and D the crown of the head out of which that neck ſprung.

Theſe eyes,to appearance, ſeem'd to be of the very ſame ſtructure with that of larger *binocular* creatures, ſeeming to have a very ſmooth and very protuberant *Cornea*,and in the midſt of it to have a very black pupil, incompaſſed about with a kind of grey *Iris*, as appears by the *Figure*; whether it were able to move theſe eyes to and fro, I have not obſerv'd, but 'tis not very likely he ſhould,the pillar or neck C, ſeeming to be cover'd and ſtiffen'd with a cruſty ſhell; but Nature,in probability,has ſupply'd

Schem XXXI

Fig: 1

g. 2.

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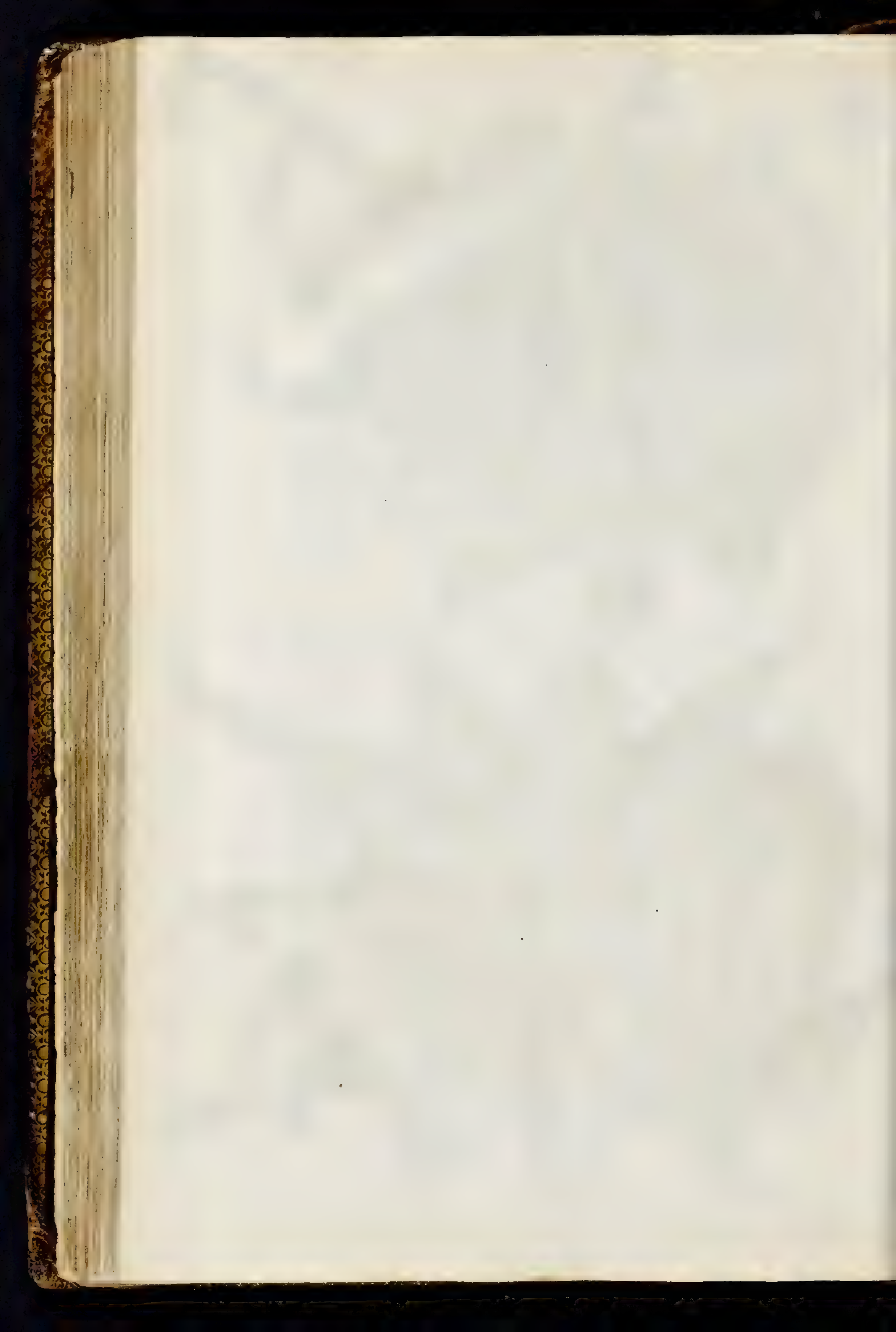
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Fig: 3

M

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A



ply'd that defect, by making the *Cornea* so very protuberant, and setting it so cleer above the shadowing or obstructing of its prospect by the body, that 'tis likely each eye may perceive, though not see distinctly, almost a *Hemisphere*, whence having so small and round a body plac'd upon such long leggs, it is quickly able so to wind, and turn it, as to see any thing distinct. This creature, as do all other Spiders I have yet examin'd, does very much differ from most other Insects in the Figure of its eyes; for I cannot, with my best *Microscope*, discover its eyes to be any ways knobb'd or pearl'd like those of other Insects.

The second Peculiarity which is obvious to the eye, is also very remarkable, and that is the prodigious length of its leggs, in proportion to its small round body, each legg of this I drew, being above sixteen times the length of its whole body, and there are some which have them yet longer, and others that seem of the same kind, that have them a great deal shorter; the eight leggs are each of them jointed, just like those of a Crab, but every of the parts are spun out prodigiously longer in proportion; each of these leggs are terminated in a small case or shell, shap'd almost like that of a Musle-shell, as is evident in the third *Figure* of the same *Scheme* (that represents the appearance of the under part or belly of the creature) by the shape of the protuberant *conical* body, I I I, *&c.* These are as 'twere plac'd or fasten'd on to the protuberant body of the Insect, which is to be suppos'd very high at M, making a kind of blunt cone whereof M is to be suppos'd the *Apex*, about which greater cone of the body, the smaller cones of the leggs are plac'd, each of them almost reaching to the top in so admirable a manner, as does not a little manifest the wisdom of Nature in the contrivance; for these long Leavers (as I may so call them) of the legs, having not the advantage of a long end on the other side of the *hypomochlion* or centers on which the parts of the leggs move, must necessarily require a vast strength to move them, and keep the body ballanc'd and suspended, in so much, that if we should suppose a man's body suspended by such a contrivance, an hundred and fifty times the strength of a man would not keep the body from falling on the breast. To supply therefore each of these leggs with its proper strength, Nature has allow'd to each a large Chest or Cell, in which is included a very large and strong Muscle, and thereby this little Animal is not onely able to suspend its body upon less then these eight, but to move it very swiftly over the tops of grass and leaves.

Nor are these eight leggs so prodigiously long, but the ninth, and tenth, which are the two claws, K K, are as short, and serve in steed of a *proboscis*, for those seem'd very little longer then his mouth; each of them had three parts, but very short, the joints K K, which represented the third, being longer then both the other. This creature, seems (which I have several times with pleasure observ'd) to throw its body upon the prey, insteed of its hands, not unlike a hunting Spider, which leaps like a Cat at a Mouse. The whole Fabrick was a very pretty one, and could I have dissected it, I doubt not but I should have found as many singularities within it as without, perhaps, for the most part, not unlike the

the parts of a Crab, which this little creature does in many things, very much resemble; the curiosity of whose contrivance, I have in another place examin'd. I omit the description of the horns, A A, of the mouth, L L, which seem'd like that of a Crab; the speckledness of his shell, which proceeded from a kind of feathers or hairs, and the hairiness of his leggs, his large *thorax* and little belly, and the like, they being manifested by the Figure; and shall onely take notice that the three parts of the body, namely, the head, breast, and belly, are in this creature strangely confus'd, so that 'tis difficult to determine which is which, as they are also in a Crab; and indeed, this seems to be nothing else, but an Air-crab, being made more light and nimble, proportionable to the *medium* wherein it resides; and as Air seems to have but one thousandth part of the body of Water, so does this Spider seem not to be a thousandth part of the bulk of a Crab.

Observ. XLVIII. *Of the hunting* Spider, *and several other sorts of* Spiders.

THe hunting Spider is a small grey Spider, prettily bespeck'd with black spots all over its body, which the *Microscope* discovers to be a kind of feathers like those on Butterflies wings, or the body of the white Moth I lately describ'd. Its gate is very nimble by fits, sometimes running, and sometimes leaping, like a Grashopper almost, then standing still, and setting it self on its hinder leggs, it will very nimbly turn its body, and look round it self every way: It has six very conspicuous eyes, two looking directly forwards, plac'd just before; two other, on either side of those, looking forward and side-ways; and two other about the middle of the top of its back or head, which look backwards and side-wards; these seem'd to be the biggest. The surface of them all was very black, sphærical, purely polish'd, reflecting a very cleer and distinct Image of all the ambient objects, such as a window, a man's hand, a white Paper, or the like. Some other properties of this Spider, observ'd by the most accomplish'd Mr. *Evelyn*, in his travels in *Italy*, are most emphatically set forth in the History hereunto annexed, which he was pleas'd upon my desire to send me in writing.

Of all the sorts of Insects, there is none has afforded me more divertisements then the *Venatores*, which are a sort of *Lupi*, that have their Denns in the rugged walls, and crevices of our houses; a small brown and delicately spotted kind of Spiders, whose hinder leggs are longer then the rest.

Such I did frequently observe at *Rome*, which espying a Fly at three or four yards distance, upon the Balcony (where I stood) would

would not make directly to her, but craul under the Rail, till being arr iv'd to the *Antipodes*, it would ſteal up, ſeldom miſſing its aim ; but if it chanced to want any thing of being perfectly oppoſite,would at firſt peep, immediatly ſlide down again, till taking better notice, it would come the next time exactly upon the Fly's back : But, if this hapn'd not to be within a compe- tent leap, then would this Inſect move ſo ſoftly, as the very ſhadow of the Gnomon ſeem'd not to be more imperceptible, unleſs the Fly mov'd ; and then would the Spider move alſo in the ſame proportion, keeping that juſt time with her motion,as if the ſame Soul had animated both thoſe little bodies ; and whether it were forwards, backwards, or to either ſide, without at all turning her body, like a well mannag'd Horſe : But, if the capricious Fly took wing, and pitch'd upon another place behind our Huntreſs, then would the Spider whirle its body ſo nimbly about, as nothing could be imagin'd more ſwift ; by which means,ſhe always kept the head towards her prey,though to appearance, as immovable, as if it had been a Nail driven into the Wood, till by that indiſcernable progreſs (being ar- riv'd within the ſphere of her reach) ſhe made a fatal leap (ſwift as Lightning) upon the Fly, catching him in the pole, where ſhe never quitted hold till her belly was full, and then carried the remainder home. I have beheld them inſtructing their young ones, how to hunt, which they would ſometimes diſcipline for not well obſerving ; but, when any of the old ones did (as ſometimes) miſs a leap, they would run out of the field, and hide them in their crannies, as aſham'd, and haply not be ſeen abroad for four or five hours after ; for ſo long have I watched the nature of this ſtrange Inſect, the con- templation of whoſe ſo wonderfull ſagacity and addreſs has amaz'd me ; nor do I find in any chaſe whatſoever, more cun- ning and Stratagem obſerv'd : I have found ſome of theſe Spi- ders in my Garden, when the weather (towards the Spring)

is very hot, but they are nothing ſo eager of hunting as they are in *Italy*.

There are multitudes of other ſorts of Spiders, whoſe eyes, and moſt other parts and properties, are ſo exceedingly different both from thoſe I have deſcrib'd, and from one another, that it would be almoſt endleſs, at leaſt too long for my preſent Eſſay, to deſcribe them,as ſome with ſix eyes, plac'd in quite another order; others with eight eyes; others with fewer, and ſome with more. They all ſeem to be creatures of prey, and to feed on other ſmall Inſects, but their ways of catching them ſeem very differing: the Shepherd Spider by running on his prey; the Hunting Spider by leaping on it,other ſorts weave Nets, or Cobwebs, whereby they enſnare them, Nature having both fitted them with materials and tools, and taught them how to work and weave their Nets, and to lie perdue, and to watch diligently to run on any Fly, as ſoon as ever entangled.

Their threads or web ſeems to be ſpun out of ſome viſcous kind of excrement, lying in their belly, which, though ſoft when drawn out, is, preſently by reaſon of its ſmalneſs, hardned and dried by the ambient Air. Examining ſeveral of which with my *Microſcope*,I found them to appear much like white Horſ-hair, or ſome ſuch tranſparent horny ſubſtance, and to be of very differing magnitudes; ſome appearing as bigg as a Pigg's briſle, others equal to a Horſ-hair; other no bigger then a man's hair; others yet ſmaller and finer. I obſerv'd further, that the radiating chords of the web were much bigger, and ſmoother then thoſe that were woven round, which ſeem'd ſmaller,and all over knotted or pearl'd, with ſmall tranſparent Globules, not unlike ſmall Cryſtal Beads or ſeed Pearls, thin ſtrung on a Clew of Silk; which, whether they were ſo ſpun by the Spider, or by the adventitious moiſture of a fogg (which I have obſerv'd to cover all theſe filaments with ſuch Cryſtalline Beads) I will not now diſpute.

Theſe threads were ſome of them ſo ſmall, that I could very plainly, with the *Microſcope*, diſcover the ſame conſecutions of colours as in a *Priſme*, and they ſeem'd to proceed from the ſame cauſe with thoſe colours which I have already deſcrib'd in thin plated bodies.

Much reſembling a Cobweb, or a confus'd lock of theſe Cylinders, is a certain white ſubſtance which, after a fogg, may be obſerv'd to fly up and down the Air; catching ſeveral of theſe, and examining them with my *Microſcope*, I found them to be much of the ſame form, looking moſt like to a flake of Worſted prepar'd to be ſpun, though by what means they ſhould be generated, or produc'd, is not eaſily imagined: they were of the ſame weight, or very little heavier then the Air; and 'tis not unlikely, but that thoſe great white clouds, that appear all the Summer time, may be of the ſame ſubſtance.

Obſerv.




Schem. XXXII
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Obſerv. XLIX. *Of an* Ant *or* Piſmire.

THis was a creature, more troubleſom to be drawn, then any of the reſt, for I could not, for a good while, think of a way to make it ſuffer its body to ly quiet in a natural poſture; but whil'ſt it was alive, if its feet were fetter'd in Wax or Glew, it would ſo twiſt and wind its body, that I could not any wayes get a good view of it; and if I killed it, its body was ſo little, that I did often ſpoile the ſhape of it, before I could throughly view it: for this is the nature of theſe minute Bodies, that as ſoon, almoſt, as ever their life is deſtroy'd, their parts immediately ſhrivel, and loſe their beauty; and ſo is it alſo with ſmall Plants, as I inſtanced before, in the deſcription of Moſs. And thence alſo is the reaſon of the variations in the beards of wild Oats, and in thoſe of Muſk-graſs ſeed, that their bodies, being exceeding ſmall, thoſe ſmall variations which are made in the ſurfaces of all bodies, almoſt upon every change of Air, eſpecially if the body be porous, do here become ſenſible, where the whole body is ſo ſmall, that it is almoſt nothing but ſurface; for as in vegetable ſubſtances, I ſee no great reaſon to think, that the moiſture of the Aire (that, ſticking to a wreath'd beard, does make it untwiſt) ſhould evaporate, or exhale away, any faſter then the moiſture of other bodies, but rather that the avolation from, or acceſs of moiſture to, the ſurfaces of bodies being much the ſame, thoſe bodies become moſt ſenſible of it, which have the leaſt proportion of body to their ſurface. So is it alſo with Animal ſubſtances; the dead body of an Ant, or ſuch little creature, does almoſt inſtantly ſhrivel and dry, and your object ſhall be quite another thing, before you can half delineate it, which proceeds not from the extraordinary exhalation, but from the ſmall proportion of body and juices, to the uſual drying of bodies in the Air, eſpecially if warm. For which inconvenience, where I could not otherwiſe remove it, I thought of this expedient.

I took the creature, I had deſign'd to delineate, and put it into a drop of very well rectified ſpirit of Wine, this I found would preſently diſpatch, as it were, the Animal, and being taken out of it, and lay'd on a paper, the ſpirit of Wine would immediately fly away, and leave the Animal dry, in its natural poſture, or at leaſt, in a conſtitution, that it might eaſily with a pin be plac'd, in what poſture you deſired to draw it, and the limbs would ſo remain, without either moving, or ſhriveling. And thus I dealt with this Ant, which I have here delineated, which was one of many, of a very large kind, that inhabited under the Roots of a Tree, from whence they would ſally out in great parties, and make moſt grievous havock of the Flowers and Fruits, in the ambient Garden, and return back again very expertly, by the ſame wayes and paths they went.

It was more then half the bigneſs of an Earwig, of a dark brown, or reddiſh colour, with long legs, on the hinder of which it would ſtand

up, and raiſe its head as high as it could above the ground, that it might ſtare the further about it, juſt after the ſame manner as I have alſo obſerv'd a hunting Spider to do: and putting my finger towards them, they have at firſt all run towards it, till almoſt at it; and then they would ſtand round about it, at a certain diſtance, and ſmell, as it were, and conſider whether they ſhould any of them venture any further, till one more bold then the reſt venturing to climb it, all the reſt, if I would have ſuffered them, would have immediately followed: many ſuch other ſeemingly rational actions I have obſerv'd in this little Vermine with much pleaſure, which would be too long to be here related; thoſe that deſire more of them may ſatisfie their curioſity in *Ligons* Hiſtory of the *Barbadoes*.

Having inſnar'd ſeveral of theſe into a ſmall Box, I made choice of the talleſt grown among them, and ſeparating it from the reſt, I gave it a Gill of Brandy, or Spirit of Wine, which after a while e'en knock'd him down dead drunk, ſo that he became moveleſs, though at firſt putting in he ſtruggled for a pretty while very much, till at laſt, certain bubbles iſſuing out of its mouth, it ceaſed to move; this (becauſe I had before found them quickly to recover again, if they were taken out preſently) I ſuffered to lye above an hour in the Spirit; and after I had taken it out, and put its body and legs into a natural poſture, remained moveleſs about an hour; but then, upon a ſudden, as if it had been awaken out of a drunken ſleep, it ſuddenly reviv'd and ran away; being caught, and ſerv'd as before, he for a while continued ſtruggling and ſtriving, till at laſt there iſſued ſeveral bubbles out of its mouth, and then, *tanquam animam expiraſſet*, he remained moveleſs for a good while; but at length again recovering, it was again redipt, and ſuffered to lye ſome hours in the Spirit; notwithſtanding which, after it had layen dry ſome three or four hours, it again recovered life and motion: Which kind of Experiments, if proſecuted, which they highly deſerve, ſeem to me of no inconſiderable uſe towards the invention of the *Latent Scheme*, (as the Noble *Verulam* calls it) or the hidden, unknown Texture of Bodies.

Of what Figure this Creature appear'd through the *Microſcope*, the 32. *Scheme* (though not ſo carefully graven as it ought) will repreſent to the eye, namely, That it had a large head A A, at the upper end of which were two protuberant eyes, pearl'd like thoſe of a Fly, but ſmaller B B; out of the Noſe, or foremoſt part, iſſued two horns C C, of a ſhape ſufficiently differing from thoſe of a blew Fly, though indeed they ſeem to be both the ſame kind of Organ, and to ſerve for a kind of ſmelling; beyond theſe were two indented jaws D D, which he open'd ſide-wayes, and was able to gape them aſunder very wide; and the ends of them being armed with teeth, which meeting went between each other, it was able to graſp and hold a heavy body, three or four times the bulk and weight of its own body: It had only ſix legs, ſhap'd like thoſe of a Fly, which, as I ſhewed before, is an Argument that it is a winged Inſect, and though I could not perceive any ſign of them in the middle part of its body (which ſeem'd to conſiſt of three joints or pie-

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ces EF G, out of which ſprung two legs, yet 'tis known that there are of them that have long wings, and fly up and down in the air.

The third and laſt part of its body I I I was bigger and larger then the other two, unto which it was joyn'd by a very ſmall middle, and had a kind of looſe ſhell, or another diſtinct part of its body H, which ſeem'd to be interpos'd, and to keep the *thorax* and belly from touching.

The whole body was cas'd over with a very ſtrong armour, and the belly III was covered likewiſe with multitudes of ſmall white ſhining briſles; the legs, horns, head, and middle parts of its body were beſtuck with hairs alſo, but ſmaller and darker.

Obſerv. L. *Of the wandring* Mite.

IN *September* and *October*, 1661. I obſerv'd in *Oxford* ſeveral of theſe little pretty Creatures to wander to and fro, and often to travel over the plains of my Window. And in *September* and *October*. 1663. I obſerv'd likewiſe ſeveral of theſe very ſame Creatures traverſing a window at *London*, and looking without the window upon the ſubjacent wall, I found whole flocks of the ſame kind running to and fro among the ſmall groves and thickets of green moſs, and upon the curiouſly ſpreading vegetable blew or yellow moſs, which is a kind of a Muſhrome or Jews-ear.

Theſe Creatures to the naked eye ſeemed to be a kind of black Mite, but much nimbler and ſtronger then the ordinary Cheeſe-Mites; but examining them in a *Microſcope*, I found them to be a very fine cruſted or ſhell'd Inſect, much like that repreſented in the firſt Figure of the three and thirtieth *Scheme*, with a protuberant oval ſhell A, indented or pitted with an abundance of ſmall pits, all covered over with little white briſles, whoſe points all directed backwards.

It had eight legs, each of them provided with a very ſharp tallon, or claw at the end, which this little Animal, in its going, faſtned into the pores of the body over which it went. Each of theſe legs were beſtuck in every joynt of them with multitudes of ſmall hairs, or (if we reſpect the proportion they bore to the bigneſs of the leg) turnpikes, all pointing towards the claws.

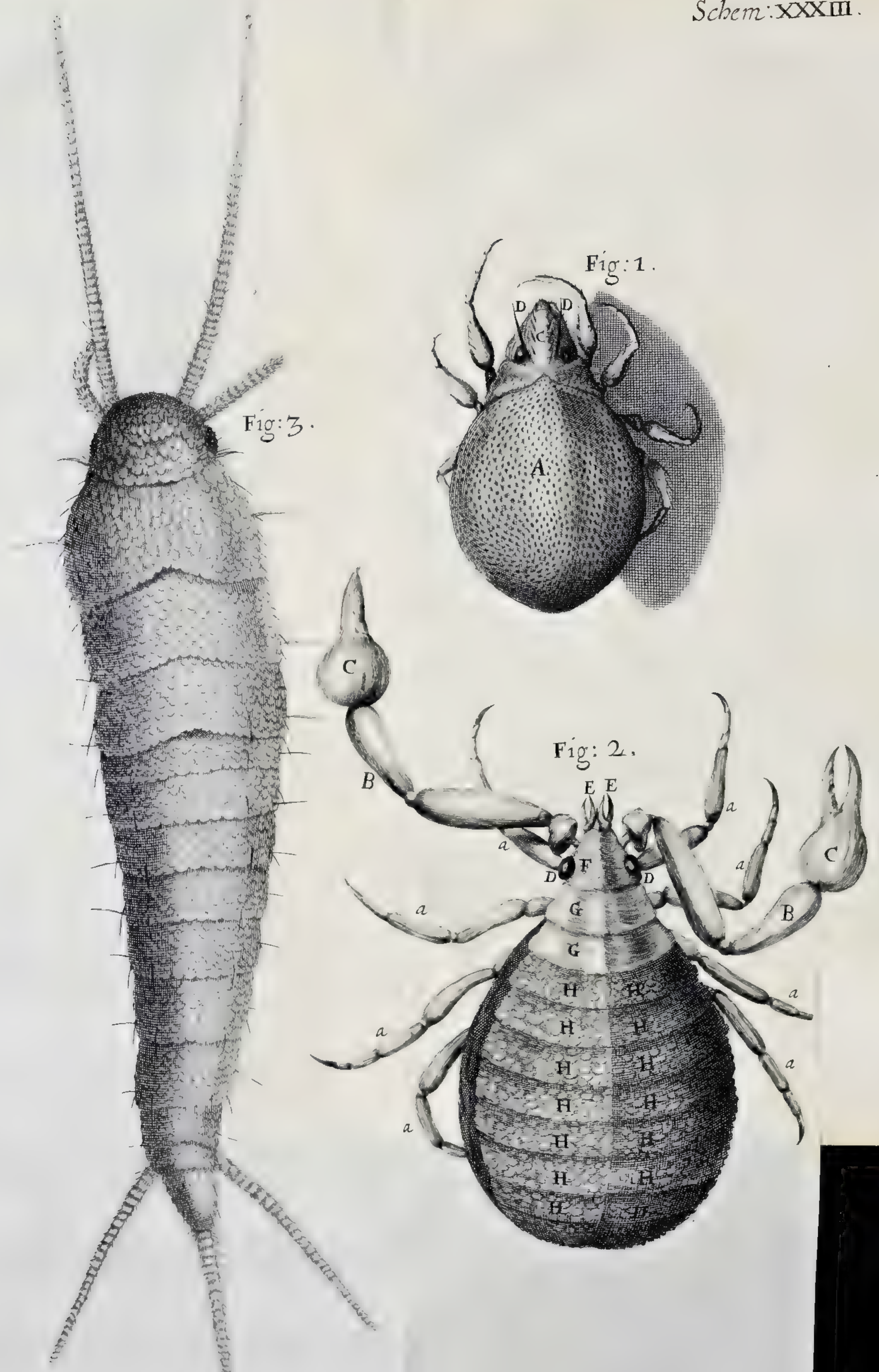
The *Thorax*, or middle parts of the body of this Creature, was exceeding ſmall, in reſpect both of the head and belly, it being nothing but that part which was covered by the two ſhells BB, though it ſeem'd to grow thicker underneath: And indeed, if we conſider the great variety Nature uſes in proportioning the three parts of the body, the *Head*, *Thorax*, and *Belly*) we ſhall not wonder at the ſmall proportion of this *Thorax*, nor at the vaſter bulk of the belly, for could we exactly anatomiſe this little Creature, and obſerve the particular deſigns of each part, we ſhould doubtleſs, as we do in all her more manageable

nageable and tractable fabricks, find much more reaſon to admire the excellency of her contrivance and workmanſhip, then to wonder, it was not made otherwiſe.

The head of this little Inſect was ſhap'd ſomewhat like a Mite's, that is,it had a long ſnout, in the manner of a Hogs, with a knobbed ridge running along the middle of it, which was beſtuck on either ſide with many ſmall briſles, all pointing forward, and two very large pikes or horns, which roſe from the top of the head, juſt over each eye, and pointed forward alſo. It had two pretty large black eyes on either ſide of the head E E, from one of which I could ſee a very bright reflection of the window, which made me gheſs, that the *Cornea* of it was ſmooth, like thoſe of bigger Inſects. Its motion was pretty quick and ſtrong, it being able very eaſily to tumble a ſtone or clod four times as big as its whole body.

At the ſame time and place, and divers times ſince, I have obſerved with my *Microſcope*, another little Inſect, which, though I have not annexed the picture of, may be worth noting, for its exceeding nimbleneſs as well as ſmalneſs; it was as ſmall as a Mite, with a body deep and ridged, almoſt like a Flea; it had eight blood-red legs, not very long, but ſlender; and two horns or feelers before. Its motion was ſo exceeding quick, that I have often loſt ſight of one I have obſerved with my naked eye; and though, when it was not frighted, I was able to follow the motions of ſome with my *Microſcope*; yet if it vvere never ſo little ſtartled, it poſted avvay vvith ſuch ſpeed, and turn'd and vvinded it ſelf ſo quick, that I ſhould preſently loſe ſight of it.

When I firſt obſerv'd the former of theſe Inſects, or Mites, I began to conjecture, that certainly I had found out the vagabond Parents of thoſe Mites we find in Cheeſes, Meal, Corn, Seeds, muſty Barrels, muſty Leather, *&c.* theſe little Creatures, vvandring to and fro every vvhither, might perhaps, as they vvere invited hither and thither by the muſty ſteams of ſeveral putrifying bodies, make their invaſions upon thoſe new and pleaſing territories, and there ſpending the remainder of their life, which might be perhaps a day, or thereabouts, in very plentiful and riotous living, might leave their off-ſpring behind them, which by the change of the ſoil and Country they now inhabite, might be quite alter'd from the hew of their *primogenitors*, and, like *Mores* tranſlated into Northern *European* Climates, after a little time, change both their skin and ſhape. And this ſeems yet more probable in theſe Inſects, becauſe that the ſoil or body they inhabit, ſeems to be almoſt half their parent, for it not only hatches and brings thoſe little eggs, or ſeminal principles, to perfection, but ſeems to augment and nouriſh them alſo before they are hatch'd or ſhaped; for it is obvious enough to be obſerv'd, that the eggs of many other Inſects, and particularly of Mites, are increas'd in bulk after they are laid out of the bodies of the Inſects, and plump'd ſometimes into many times their former bigneſs, ſo that the bodies they are laid in being, as it were, half their mothers, we ſhall not wonder that it ſhould have ſuch an active power to change their forms. We find by relations,


Schem: XXXIII.
Fig: 1.
Fig: 2.
Fig: 3.
A
B
C
D
E
F
G
H
a

relations how much the *Negro* Women do besmeer the of-spring of the *Spaniard*, bringing forth neither white-skinn'd nor black, but tawny hided *Mulattos*.

Now, though I propound this as probable, I have not yet been so farr certify'd by Observations as to conclude any thing, either positively or negatively, concerning it. Perhaps, some more lucky diligence may please the curious Inquirer with the discovery of this, to be a truth, which I now conjecture, and may thereby give him a satisfactory account of the cause of those creatures, whose original seems yet so obscure, and may give him cause to believe, that many other animate beings, that seem also to be the mere product of putrifaction, may be innobled with a Pedigree as ancient as the first creation, and farr exceed the greatest beings in their numerous Genealogies. But on the other side, if it should be found that these, or any other animate body, have no immediate similar Parent, I have in another place set down a conjectural *Hypothesis* whereby those *Phænomena* may likely enough be solv'd, wherein the infinite wisdom and providence of the Creator is no less rare and wonderfull.

Observ. L I. *Of the* Crab-like *Insect*.

Reading one day in *Septemb.* I chanced to observe a very smal creature creep over the Book I was reading, very slowly; having a *Microscope* by me, I observ'd it to be a creature of a very unusual form, and that not less notable; such as is describ'd in the second *Figure* of the 33. *Scheme*. It was about the bigness of a large Mite, or somewhat longer, it had ten legs, eight of which, A A A A, were topt with very sharp claws, and were those upon which he walk'd, seeming shap'd much like those of a Crab, which in many other things also this little creature resembled; for the two other claws, B B, which were the formost of all the ten, and seem'd to grow out of his head, like the horns of other Animals, were exactly form'd in the manner of Crabs or Lobsters claws, for they were shap'd and jointed much like those represened in the *Scheme*, and the ends of them were furnish'd with a pair of claws or pincers, C C, which this little animal did open and shut at pleasure: It seem'd to make use of those two horns or claws both for feelers and holders; for in its motion it carried these aloft extended before, moving them to and fro, just as a man blindfolded would do his hands when he is fearfull of running against a wall, and if I put a hair to it, it would readily take hold of it with these claws, and seem to hold it fast. Now, though these horns seem'd to serve him for two uses, namely, for feeling and holding; yet he seem'd neither blind, having two small black spots, D D, which by the make of them, and the bright reflection from them seem'd to be his eyes; nor did it want other hands, having another pair of claws, E E, very neer plac'd to its mouth, and seem'd adjoining to it.

The whole body was cased over with armour-shells, as is usuall in all

thoſe kinds of *cruſtaceous* creatures, eſpecially about their bellies, and ſeem'd of three kinds; the head F ſeem'd cover'd with a kind of ſcaly ſhell, the *thorax* with two ſmooth ſhells, or Rings, G G, and the belly with eight knobb'd ones. I could not certainly find whether it had under theſe laſt ſhells any wings, but I ſuſpect the contrary; for I have not found any wing'd Inſect with eight leggs, two of thoſe leggs being always converted into wings, and, for the moſt part, thoſe that have but ſix, have wings.

This creature, though I could never meet with more then one of them, and ſo could not make ſo many examinations of it as otherwiſe I would, I did notwithſtanding, by reaſon of the great curioſity that appear'd to me in its ſhape, delineate it, to ſhew that, in all likelihood, Nature had crouded together into this very minute Inſect, as many, and as excellent contrivances, as into the body of a very large Crab, which exceeds it in bulk, perhaps, ſome Millions of times; for as to all the apparent parts, there is a greater rather then a leſs multiplicity of parts, each legg has as many parts, and as many joints as a Crabs, nay, and as many hairs or briſles; and the like may be in all the other viſible parts; and 'tis very likely, that the internal curioſities are not leſs excellent: It being a general rule in Nature's proceedings, that where ſhe begins to diſplay any excellency, if the ſubject be further ſearch'd into, it will manifeſt, that there is not leſs curioſity in thoſe parts which our ſingle eye cannot reach, then in thoſe which are more obvious.

Obſerv. LII. *Of the ſmall Silver-colour'd* Book-worm.

As among greater Animals there are many that are ſcaled, both for ornament and defence, ſo are there not wanting ſuch alſo among the leſſer bodies of Inſects, whereof this little creature gives us an Inſtance. It is a ſmall white Silver-ſhining Worm or Moth, which I found much converſant among Books and Papers, and is ſuppos'd to be that which corrodes and eats holes through the leaves and covers; it appears to the naked eye, a ſmall gliſtering Pearl-colour'd Moth, which upon the removing of Books and Papers in the Summer, is often obſerv'd very nimbly to ſcud, and pack away to ſome lurking cranney, where it may the better protect it ſelf from any appearing dangers. Its head appears bigg and blunt, and its body tapers from it towads the tail, ſmaller and ſmaller, being ſhap'd almoſt like a Carret.

This the *Microſcopical* appearance will more plainly manifeſt, which exhibits, in the third *Figure* of the 33. *Scheme*, a conical body, divided into fourteen ſeveral partitions, being the appearance of ſo many ſeveral ſhels, or ſhields that cover the whole body, every of theſe ſhells are again cover'd or tiled over with a multitude of thin tranſparent ſcales, which, from the multiplicity of their reflecting ſurfaces, make the whole Animal appear of a perfect Pearl-colour.

Which,by the way,may hint us the reaſon of that ſo much admired appearance of thoſe ſo highly eſteem'd bodies, as alſo of the like in mother of Pearl-ſhells, and in multitudes of other ſhelly Sea-ſubſtances; for they each of them conſiſting of an infinite number of very thin ſhells or laminated orbiculations, cauſe ſuch multitudes of reflections, that the compoſitions of them together with the reflections of others that are ſo thin as to afford colours (of which I elſewhere give the reaſon) gives a very pleaſant reflection of light. And that this is the true cauſe,ſeems likely, firſt, becauſe all thoſe ſo appearing bodies are compounded of multitudes of plated ſubſtances. And next that by ordering any traſparent ſubſtance after this manner,the like *Phænomena* may be produc'd; this will be made very obvious by the blowing of Glaſs into exceeding thin ſhells, and then breaking them into ſcales,which any lamp-worker will preſently do; for a goodquantity of theſe ſcales,laid in a heap together,have much the ſame reſemblance of Pearls. Another way, not leſs inſtructive and pleaſant, is a way which I have ſeveral times done, which is by working and toſſing,as 'twere, a parcel of pure cryſtalline glaſs whilſt it is kept glowing hot in the blown flame of a Lamp, for,by that means,that purely tranſparent body will be ſo divided into an infinite number of plates, or ſmall ſtrings, with interpos'd aerial plates and *fibres*, that from the multiplicity of the reflections from each of thoſe internal ſurfaces, it may be drawn out into curious Pearl-like or Silver wire, which though ſmall, will yet be opacous; the ſame thing I have done with a compoſition of red *Colophon* and *Turpentine*, and a little Bee's Wax, and may be done likewiſe with Birdlime, and ſuch like glutinous and tranſparent bodies: But to return to our deſcription.

The ſmall blunt head of this Inſect was furniſh'd on either ſide of it with a cluſter of eyes, each of which ſeem'd to contain but a very few, in compariſon of what I had obſerv'd the cluſters of other Inſects to abound with; each of theſe cluſters were beſet with a row of ſmall briſles, much like the *cilia* or hairs on the eye-lids, and, perhaps, they ſerv'd for the ſame purpoſe. It had two long horns before, which were ſtreight, and tapering towards the top, curiouſly ring'd or knobb'd, and briſled much like the Marſh Weed, call'd Horſe-tail, or Cats-tail, having at each knot a fring'd Girdle,as I may ſo call it, of ſmaller hairs, and ſeveral bigger and larger briſles,here and there diſpers'd among them: beſides theſe, it had two ſhorter horns, or feelers, which were knotted and fring'd, juſt as the former, but wanted briſles, and were blunt at the ends; the hinder part of the creature was terminated with three tails, in every particular reſembling the two longer horns that grew out of the head: The leggs of it were ſcal'd and hair'd much like the reſt, but are not expreſs'd in this *Figure*, the Moth being intangled all in Glew, and ſo the leggs of this appear'd not through the Glaſs which looked perpendicularly upon the back.

This Animal probably feeds upon the Paper and covers of Books, and perforates in them ſeveral ſmall round holes, finding, perhaps, a convenient nouriſhment in thoſe huſks of Hemp and Flax, which have paſs'd

through ſo many ſcourings, waſhings,dreſſings and dryings, as the parts of old Paper muſt neceſſarily have ſuffer'd; the digeſtive faculty,it ſeems, of theſe little creatures being able yet further to work upon thoſe ſtubborn parts, and reduce them into another form.

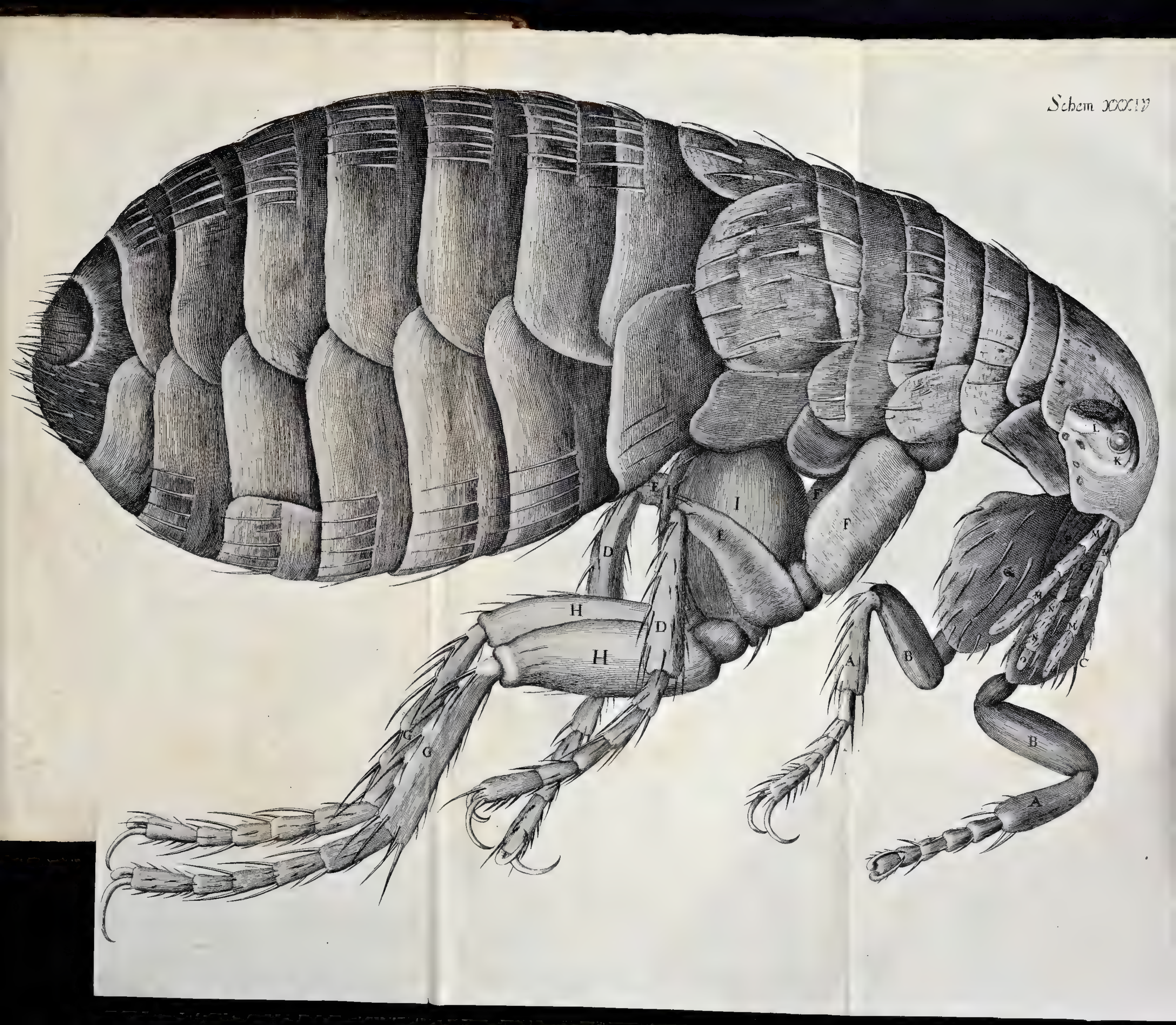
And indeed, when I conſider what a heap of Saw-duſt or chips this little creature (which is one of the teeth of Time) conveys into its intrals. I cannot chuſe but remember and admire the excellent contrivance of Nature, in placing in Animals ſuch a fire, as is continually nouriſhed and ſupply'd by the materials convey'd into the ſtomach, and *fomented* by the bellows of the lungs; and in ſo contriving the moſt admirable fabrick of Animals, as to make the very ſpending and waſting of that fire, to be inſtrumental to the procuring and collecting more materials to augment and cheriſh it ſelf, which indeed ſeems to be the principal end of all the contrivances obſervable in bruit Animals.

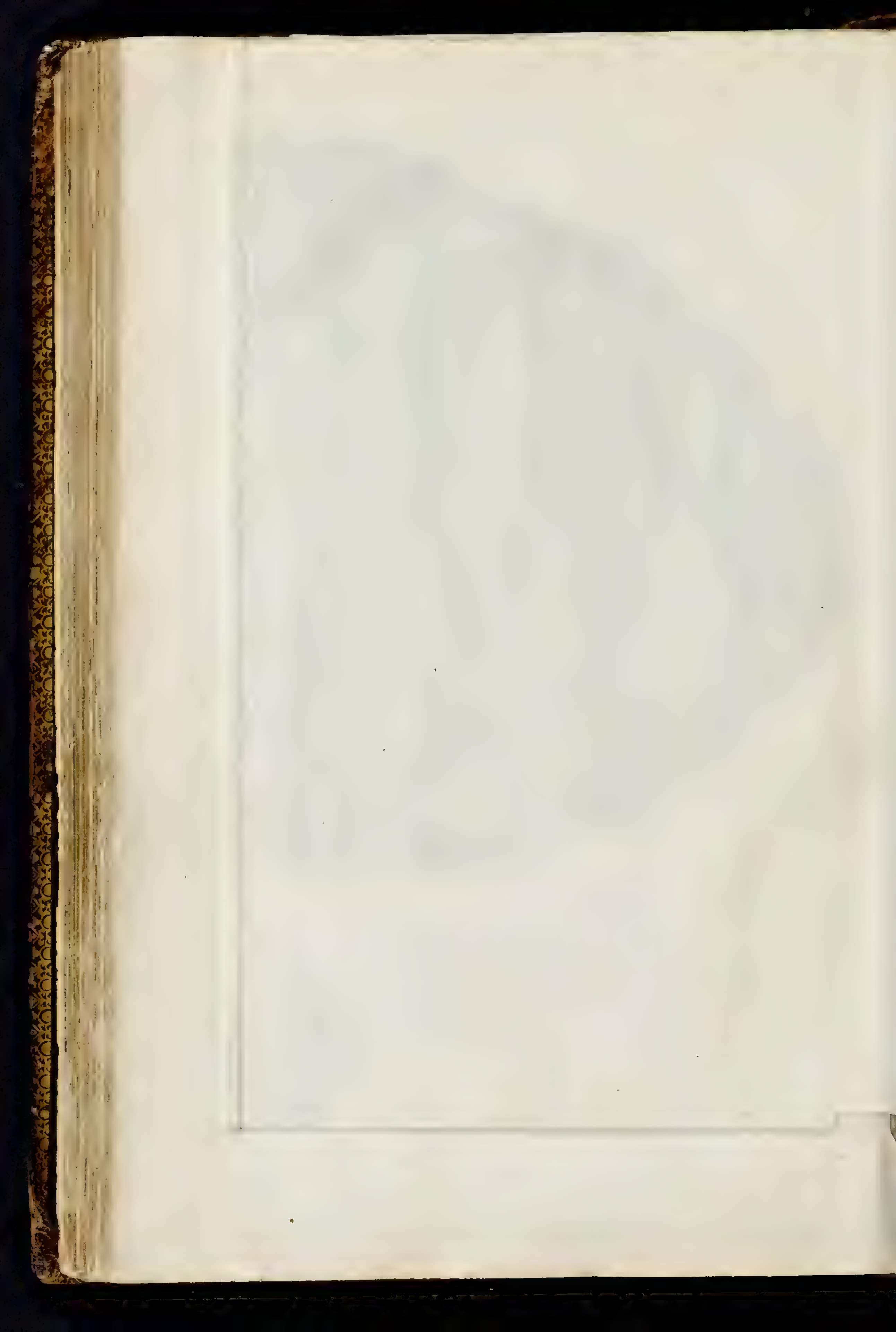
Obſerv. LIII. *Of a* Flea.

THe ſtrength and beauty of this ſmall creature, had it no other relation at all to man, would deſerve a deſcription.

For its ſtrength, the *Microſcope* is able to make no greater diſcoveries of it then the naked eye, but onely the curious contrivance of its leggs and joints, for the exerting that ſtrength,is very plainly manifeſted, ſuch as no other creature, I have yet obſerv'd, has any thing like it; for the joints of it are ſo adapted,that he can,as 'twere,fold them ſhort one within another,and ſuddenly ſtretch,or ſpring them out to their whole length, that is, of the fore-leggs, the part A, of the 34. *Scheme*, lies within B, and B within C, parallel to, or ſide by ſide each other; but the parts of the two next, lie quite contrary, that is, D without E, and E without F, but parallel alſo; but the parts of the hinder leggs, G, H and I, bend one within another, like the parts of a double jointed Ruler, or like the foot, legg and thigh of a man; theſe ſix leggs he clitches up altogether, and when he leaps, ſprings them all out, and thereby exerts his whole ſtrength at once.

But, as for the beauty of it, the *Microſcope* manifeſts it to be all over adorn'd with a curiouſly poliſh'd ſuit of *ſable* Armour, neatly jointed, and beſet with multitudes of ſharp pinns, ſhap'd almoſt like Porcupine's Quills, or bright conical Steel-bodkins; the head is on either ſide beautify'd with a quick and round black eye K, behind each of which alſo appears a ſmall cavity, L, in which he ſeems to move to and fro a certain thin film beſet with many ſmall tranſparent hairs,which probably may be his ears; in the forepart of his head, between the two fore-leggs, he has two ſmall long jointed feelers, or rather ſmellers, M M, which have four joints,and are hairy, like thoſe of ſeveral other creatures; between theſe, it has a ſmall *proboſcis*, or *probe*, N N O, that ſeems to conſiſt of a tube,


Schem XXXIV
L
K
I
E
F
F
D
D
H
H
G
G
A
B
B
A
C
M
N
O



tube N N, and a tongue or fucker O, which I have perceiv'd him to flip in and out. Befides thefe, it has alfo two chaps or biters P P, which are fomewhat like thofe of an Ant, but I could not perceive them tooth'd; thefe were fhap'd very like the blades of a pair of round top'd Scizers, and were opened and fhut juft after the fame manner; with thefe Inftruments does this little bufie Creature bite and pierce the fkin, and fuck out the blood of an Animal, leaving the fkin inflamed with a fmall round red fpot. Thefe parts are very difficult to be difcovered, becaufe, for the moft part, they lye covered between the fore-legs. There are many other particulars, which, being more obvious, and affording no great matter of information, I fhall pafs by, and refer the Reader to the Figure.

Obferv. LIV. *Of a Loufe.*

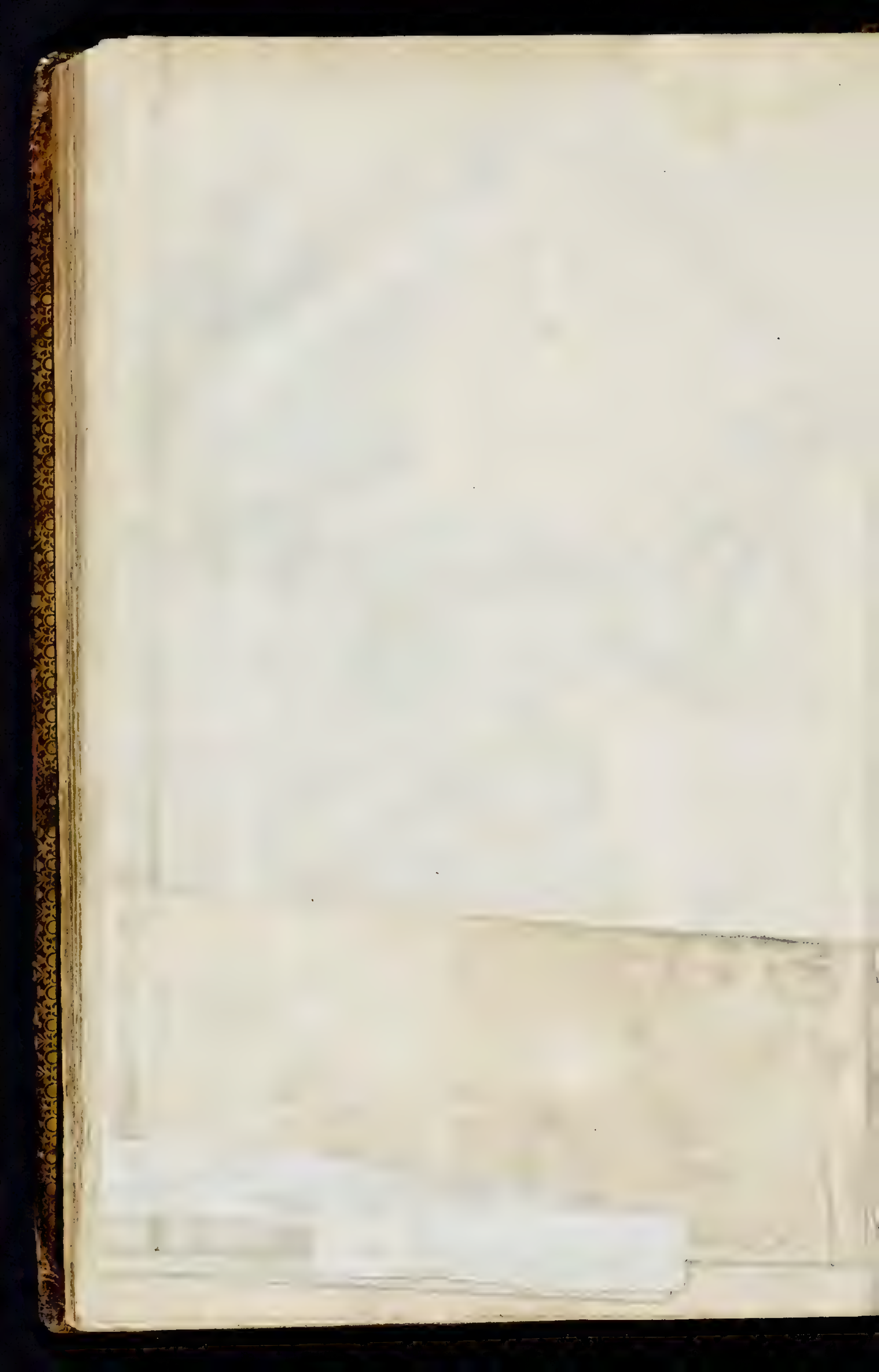
THis is a Creature fo officious, that 'twill be known to every one at one time or other, fo bufie, and fo impudent, that it will be intruding it felf in every ones company, and fo proud and afpiring withall, that it fears not to trample on the beft, and affects nothing fo much as a Crown; feeds and lives very high, and that makes it fo faucy, as to pull any one by the ears that comes in its way, and will never be quiet till it has drawn blood: it is troubled at nothing fo much as at a man that fcratches his head, as knowing that man is plotting and contriving fome mifchief againft it, and that makes it oftentime fculk into fome meaner and lower place, and run behind a mans back, though it go very much againft the hair; which ill conditions of it having made it better known then trufted, would exempt me from making any further defcription of it, did not my faithful *Mercury*, my *Microfcope*, bring me other information of it. For this has difcovered to me, by means of a very bright light caft on it, that it is a Creature of a very odd fhape; it has a head fhap'd like that expreft in 35. *Scheme* marked with A, which feems almoft Conical, but is a little flatted on the upper and under fides, at the biggeft part of which, on either fide behind the head (as it were, being the place where other Creatures ears ftand) are placed its two black fhining goggle eyes B B, looking backwards, and fenced round with feveral fmall *cilia* or hairs that incompafs it, fo that it feems this Creature has no very good forefight: It does not feem to have any eye-lids, and therefore perhaps its eyes were fo placed, that it might the better cleanfe them with its fore-legs; and perhaps this may be the reafon, why they fo much avoid and run from the light behind them, for being made to live in the fhady and dark receffes of the hair, and thence probably their eye having a great aperture, the open and clear light, efpecially that of the Sun, muft needs very much offend them; to fecure thefe eyes from receiving any injury from the hairs through which it paffes, it has

two horns that grow before it, in the place where one would have thought the eyes ſhould be ; each of theſe C C hath four joynts, which are fringed, as 'twere, with ſmall briſtles, from which to the tip of its ſnout D, the head ſeems very round and tapering, ending in a very ſharp noſe D, which ſeems to have a ſmall hole, and to be the paſſage through which he ſucks the blood. Now whereas if it be plac'd on its back, with its belly upwards, as it is in the 35. *Scheme*, it ſeems in ſeveral Poſitions to have a reſemblance of chaps, or jaws, as is repreſented in the Figure by E E, yet in other poſtures thoſe dark ſtrokes diſappear ; and having kept ſeveral of them in a box for two or three dayes, ſo that for all that time they had nothing to feed on, I found, upon letting one creep on my hand, that it immediately fell to ſucking, and did neither ſeem to thruſt its noſe very deep into the ſkin, nor to open any kind of mouth, but I could plainly perceive a ſmall current of blood, which came directly from its ſnout, and paſt into its belly ; and about A there ſeem'd a contrivance, ſomewhat reſembling a Pump, pair of Bellows, or Heart, for by a very ſwift *ſyſtole* and *diaſtole* the blood ſeem'd drawn from the noſe, and forced into the body. It did not ſeem at all, though I viewed it a good while as it was ſucking, to thruſt more of its noſe into the ſkin then the very ſnout D, nor did it cauſe the leaſt diſcernable pain, and yet the blood ſeem'd to run through its head very quick and freely, ſo that it ſeems there is no part of the ſkin but the blood is diſpers'd into, nay, even into the *cuticula* ; for had it thruſt its whole noſe in from D to C C, it would not have amounted to the ſuppoſed thickneſs of that *tegument*, the length of the noſe being not more then a three hundredth part of an inch. It has ſix legs, covered with a very tranſparent ſhell, and joynted exactly like a Crab's, or Lobſter's ; each leg is divided into ſix parts by theſe joynts, and thoſe have here and there ſeveral ſmall hairs ; and at the end of each leg it has two claws, very properly adapted for its peculiar uſe, being thereby inabled to walk very ſecurely both on the ſkin and hair ; and indeed this contrivance of the feet is very curious, and could not be made more commodiouſly and compendiouſly, for performing both theſe requiſite motions, of walking and climbing up the hair of a mans head, then it is : for, by having the leſſer claw (a) ſet ſo much ſhort of the bigger (b) when it walks on the ſkin the ſhorter touches not, and then the feet are the ſame with thoſe of a Mite, and ſeveral other ſmall Inſects, but by means of the ſmall joynts of the longer claw it can bend it round, and ſo with both claws take hold of a hair, in the manner repreſented in the Figure, the long tranſparent Cylinder F F F, being a Man's hair held by it.

The *Thorax* ſeem'd cas'd with another kind of ſubſtance then the belly, namely, with a thin tranſparent horny ſubſtance, which upon the faſting of the Creature did not grow flaccid ; through this I could plainly ſee the blood, ſuck'd from my hand, to be variouſly diſtributed, and mov'd to and fro ; and about G there ſeem'd a pretty big white ſubſtance, which ſeem'd to be moved within its *thorax* ; beſides, there appear'd very many ſmall milk-white veſſels, which croſt over the breaſt

between


Schem XXXV.
D
E
C
C
A
B
B
F
b
b
b
a
F
F
H
H
I
I



between the legs, out of which, on either ſide, were many ſmall branchings,theſe ſeem'd to be the veins and arteries,for that which is analogus to blood in all Inſects is milk-white.

The belly is covered with a tranſparent ſubſtance likewiſe, but more reſembling a ſkin then a ſhell, for 'tis grain'd all over the belly juſt like the skin in the palms of a man's hand, and when the belly is empty,grows very flaccid and wrinkled; at the upper end of this is placed the ſtomach H H,and perhaps alſo the white ſpot I I may be the liver,or *pancreas*, which,by the *periſtaltick* motion of the guts, is a little mov'd to and fro, not with a *ſyſtole* and *diaſtole*, but rather with a thronging or juſtling motion. Viewing one of theſe Creatures, after it had faſted two dayes, all the hinder part was lank and flaccid, and the white ſpot I I hardly mov'd, moſt of the white branchings diſappear'd, and moſt alſo of the redneſs or ſucked blood in the guts, the *periſtaltick* motion of which was ſcarce diſcernable; but upon the ſuffering it to ſuck, it preſently fill'd the ſkin of the belly, and of the ſix ſcolop'd emboſments on either ſide, as full as it could be ſtuft; the ſtomach and guts were as full as they could hold; the *periſtaltick* motion of the gut grew quick,and the juſtling motion of I I accordingly; multitudes of milk-white veſſels ſeem'd quickly filled, and turgid, which were perhaps the veins and arteries, and the Creature was ſo greedy, that though it could not contain more, yet it continued ſucking as faſt as ever, and as faſt emptying it ſelf behind: the digeſtion of this Creature muſt needs be very quick, for though I perceiv'd the blood thicker and blacker when ſuck'd, yet, when in the guts, it was of a very lovely ruby colour, and that part of it, which was digeſted into the veins, ſeemed white; whence it appears, that a further digeſtion of blood may make it milk, at leaſt of a reſembling colour: What is elſe obſervable in the figure of this Creature, may be ſeen by the 35. *Scheme*.

Obſerv. LV. *Of* Mites.

THe leaſt of *Reptiles* I have hitherto met with, is a Mite, a Creature whereof there are ſome ſo very ſmall, that the ſharpeſt ſight, unaſſiſted with Glaſſes, is not able to diſcern them, though, being white of themſelves, they move on a black and ſmooth ſurface; and the Eggs, out of which theſe Creatures ſeem to be hatch'd, are yet ſmaller, thoſe being uſually not above a four or five hundredth part of a well grown Mite, and thoſe well grown Mites not much above one hundredth of an inch in thickneſs; ſo that according to this reckoning there may be no leſs then a million of well grown Mites contain'd in a cubick inch, and five hundred times as many Eggs.

Notwithſtanding which minuteneſs a good *Microſcope* diſcovers thoſe ſmall movable ſpecks to be very prettily ſhap'd Inſects, each of them furniſh'd

nish'd with eight well shap'd and proportion'd legs, which are each of them joynted or bendable in eight several places, or joynts, each of which is covered, for the most part, with a very transparent shell, and the lower end of the shell of each joynt is fringed with several small hairs; the contrivance of the joynts seems the very same with that of Crabs and Lobsters legs, and like those also, they are each of them terminated with a very sharp claw or point; four of these legs are so placed, that they seem to draw forwards, the other four are placed in a quite contrary position, thereby to keep the body backwards when there is occasion.

Fig. 1. Schem. 36. The body, as in other larger Insects, consists of three regions or parts; the hinder or belly A, seems covered with one intire shell, the middle, or chest, seems divided into two shells B C. which running one within the other, the Mite is able to shrink in and thrust out as it finds occasion, as it can also the snout D. The whole body is pretty transparent, so that being look'd on against the light, divers motions within its body may be perceived; as also all the parts are much more plainly delineable, then in other postures, to the light. The shell, especially that which covers the back, is curiously polisht, so that 'tis easie to see, as in a *convex* Looking-glass, or *foliated* Glass-ball, the picture of all the objects round about; up and down, in several parts of its body, it has several small long white hairs growing out of its shell, which are often longer then the whole body, and are represented too short in the first and second Figures; they seem all pretty straight and plyable, save only two upon the fore-part of its body, which seem to be the horns, as may be seen in the Figures; the first whereof is a prospect of a smaller sort of Mites (which are usually more plump) as it was *passant* to and fro; the second is the prospect of one fixt on its tail (by means of a little mouth-glew rub'd on the object plate) exhibiting the manner of the growing of the legs, together with their several joynts.

This Creature is very much diversify'd in shape, colour, and divers other properties, according to the nature of the substance out of which it seems to be ingendred and nourished, being in one substance more long, in another more round, in some more hairy, in others more smooth, in this nimble, in that slow, here pale and whiter, there browner, blacker, more transparent, *&c.* I have observed it to be resident almost on all kinds of substances that are mouldy, or putrifying, and have seen it very nimbly meshing through the thickets of mould, and sometimes to lye *dormant* underneath them; and 'tis not unlikely but that it may feed on that vegetating substance, *spontaneous Vegetables* seeming a food proper enough for *spontaneous Animals*,

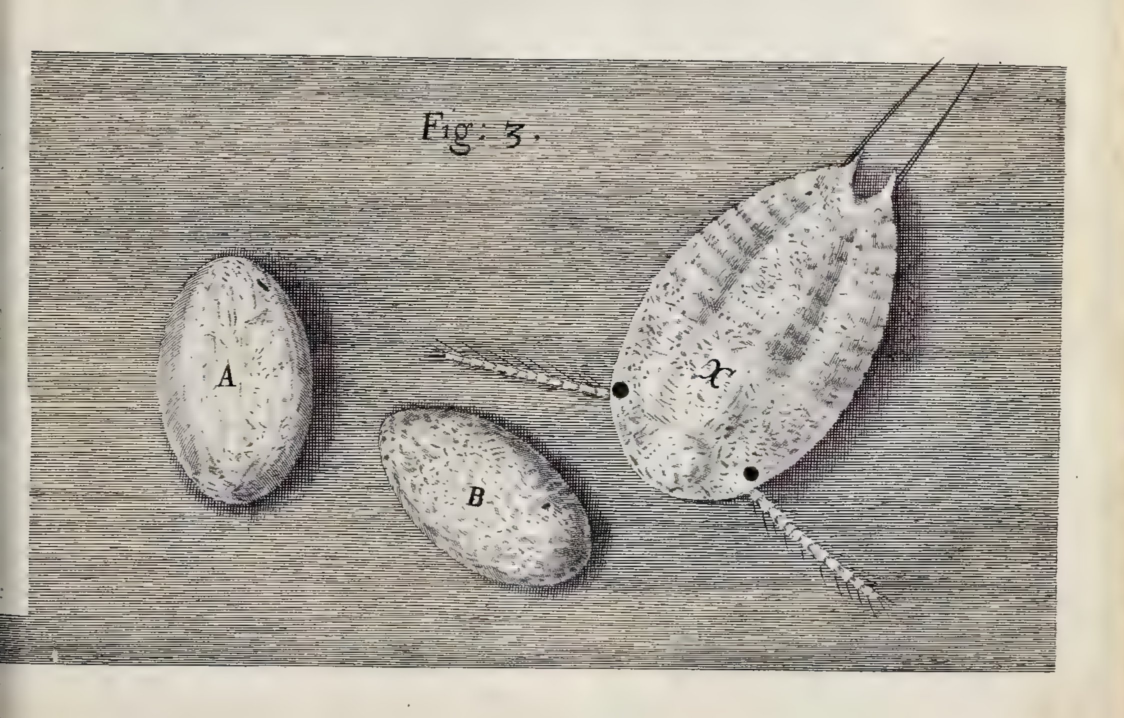
But whether indeed this Creature, or any other, be such or not, I cannot positively, from any Experiment, or Observation, I have yet made, determine. But, as I formerly hinted, it seems probable, that some kind of wandring Mite may sow, as 'twere, the first seeds, or lay the first eggs, in those places, which Nature has instructed them to know convenient for the hatching and nourishing their young; and though perhaps the

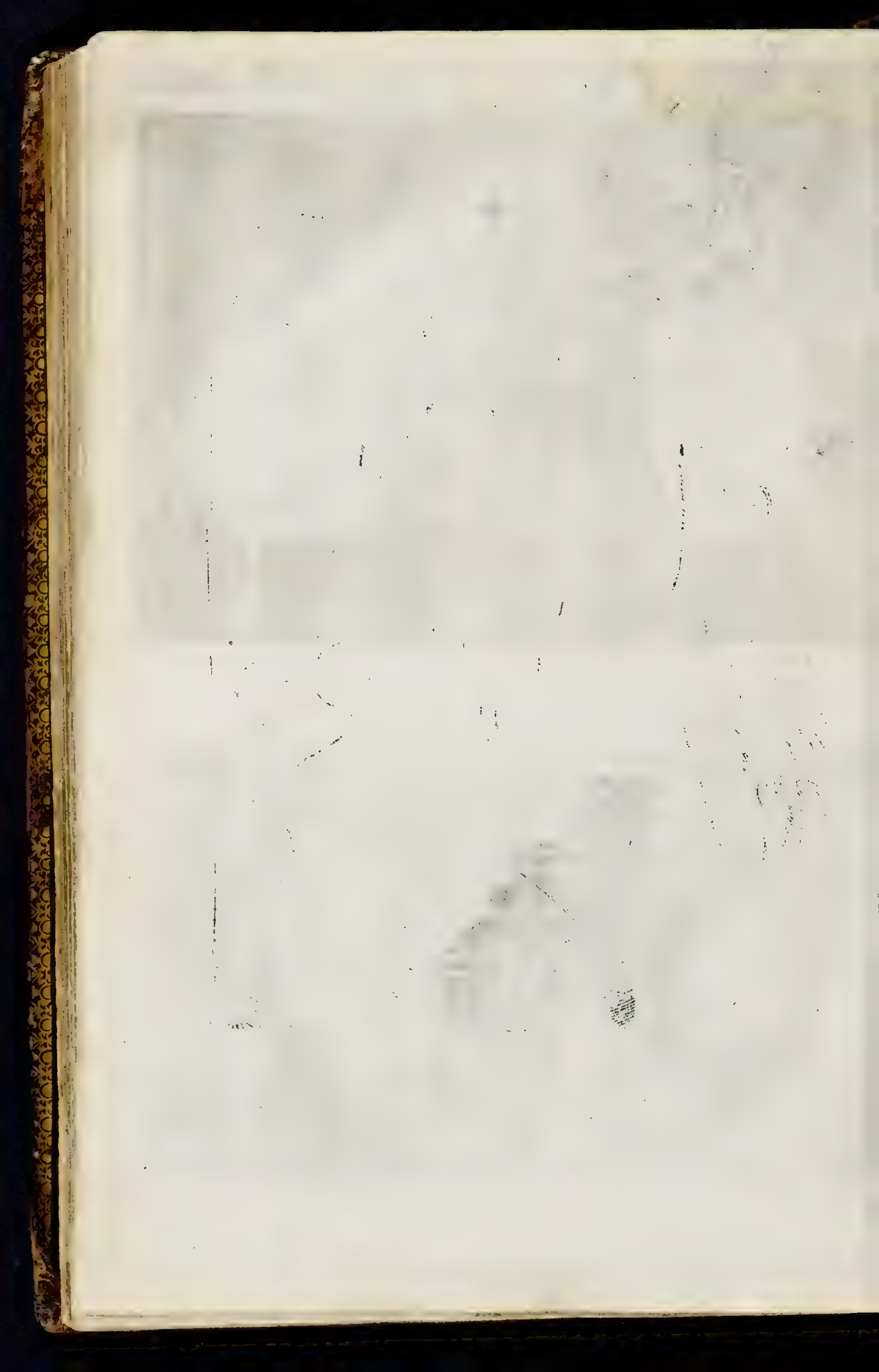
prime

Fig:1.

A

Fig:2.





prime Parent might be of a ſhape very differing from what the off-ſpring, after a little while, by reaſon of the ſubſtance they feed on, or the Region (as 'twere) they inhabite; yet perhaps even one of theſe alter'd progeny, wandering again from its native ſoil, and lighting on by chance the ſame place from whence its prime Parent came, and there ſettling, and planting, may produce a generation of Mites of the ſame ſhapes and properties with the firſt wandring Mite: And from ſome ſuch accidents as theſe, I am very apt to think, the moſt ſorts of Animals, generally accounted *ſpontaneous*, have their *origination*, and all thoſe various ſorts of Mites, that are to be met with up and down in divers putrifying ſubſtances, may perhaps be all of the ſame kind, and have ſprung from one and the ſame ſort of Mites at the firſt.

Obſerv. LVI. *Of a ſmall Creature hatch'd on a Vine.*

THere is, almoſt all the Spring and Summer time, a certain ſmall, round, white Cobweb, as 'twere, about the bigneſs of a Pea, which ſticks very cloſe and faſt to the ſtocks of Vines nayl'd againſt a warm wall: being attentively viewed, they ſeem cover'd, upon the upper ſide of them, with a ſmall husk, not unlike the ſcale, or ſhell of a Wood-louſe, or Hog-louſe, a ſmall Inſect uſually found about rotten wood, which upon touching preſently rouls it ſelf into the form of a pepper-corn: Separating ſeveral of theſe from the ſtock, I found them, with my *Microſcope*, to conſiſt of a ſhell, which now ſeemed more likely to be the huſk of one of theſe Inſects: And the fur ſeem'd a kind of cobweb, conſiſting of abundance of ſmall filaments, or ſleaves of cobwebs. In the midſt of this, if they were not hatch'd, and run away before, the time of which hatching was uſually about the latter end of *June*, or beginning of *July*, I have often found abundance of ſmall brown Eggs, ſuch as A and B in the ſecond Figure of the 36. *Scheme*, much about the bigneſs of Mites Eggs; and at other times, multitudes of ſmall Inſects, ſhaped exactly like that in the third Figure marked with X. Its head large, almoſt half the bigneſs of its body, which is uſual in the *fœtus* of moſt Creatures. It had two ſmall black eyes *a a*, and two ſmall long joynted and briſled horns *b b*. The hinder part of its body ſeem'd to conſiſt of nine ſcales, and the laſt ended in a forked tayl, much like that of a *Cutio*, or Wood-louſe, out of which grew two long hairs; they ran to and fro very ſwiftly, and were much of the bigneſs of a common Mite, but ſome of them leſs: The longeſt of them ſeem'd not the hundredth part of an inch, and the Eggs uſually not above half as much. They ſeemed to have ſix legs, which were not viſible in this I have here delineated, by reaſon they were drawn under its body.

If theſe Minute creatures were *Wood-lice* (as indeed from their own ſhape and frame, the ſkin, or ſhell, that grows on them, one may with great probability

bability ghefs) it affords us an Inftance, whereof perhaps there are not many like in Nature,and that is,of the prodigious increafe of thefe Creatures,after they are hatch'd and run about ;for a common Wood-loufe,of about half an inch long, is no lefs then a hundred and twenty five thoufand times bigger then one of thefe, which though indeed it feems very ftrange, yet I have obferved the young ones of fome Spiders have almoft kept the fame proportion to their Dam.

This, methinks, if it be fo, does in the next place hint a Quæry,which may perhaps deferve a little further examination : And that is,Whether there be not many of thofe minute Creatures,fuch as Mites, and the like, which, though they are commonly thought of otherwife, are only the *pully*, or young ones, of much bigger Infects, and not the generating, or parent Infect, that has layd thofe Eggs ; for having many times obferv'd thofe Eggs, which ufually are found in great abundance where Mites are found , it feems fomething ftrange, that fo fmall an Animal fhould have an Egg fo big in proportion to its body. Though on the other fide, I muft confefs, that having kept divers of thofe Mites inclofed in a box for a good while, I did not find them very much augmented beyond their ufual bignefs.

What the husk and cobweb of this little white fubftance fhould be, I cannot imagine, unlefs it be, that the old one, when impregnated with Eggs, fhould there ftay, and fix it felf on the Vine, and dye, and all the body by degrees fhould rot, fave only the husk, and the Eggs in the body : And the heat, or fire, as it were, of the approaching Sun-beams fhould vivifie thofe Relicts of the corrupted Parent , and out of the afhes, as 'twere, (as it is fabled of the *Phœnix*) fhould raife a new offfpring for the perpetuation of the *fpecies*. Nor will the cobweb , as it were, in which thefe Eggs are inclos'd, make much againft this Conjecture ; for we may, by thofe cobwebs that are carried up and down the Air after a Fog (which with my *Microfcope* I have difcovered to be made up of an infinite company of fmall filaments or threads) learn , that fuch a texture of body may be otherwife made then by the fpinning of a Worm.

Obferv. LVII. *Of the* Eels *in Vinegar*.

OF thefe fmall Eels, which are to be found in divers forts of Vinegar, I have little to add befides their Picture, which you may find drawn in the third Figure of the 25. *Scheme* : That is, they were fhaped much like an Eel, fave only that their nofe A, (which was a little more opacous then the reft of their body) was a little fharper, and longer, in proportion to their body, and the wrigling motion of their body feem'd to be onely upwards and downwards, whereas that of Eels is onely fide wayes : They feem'd to have a more opacous part about

about B, which might, perhaps, be their Gills; it ſeeming always the ſame proportionate diſtant from their noſe, from which, to the tip of their tail, C, their body ſeem'd to taper.

Taking ſeveral of theſe out of their Pond of Vinegar, by the net of a ſmall piece of filtring Paper, and laying them on a black ſmooth Glaſs plate, I found that they could wriggle and winde their body, as much almoſt as a Snake, which made me doubt, whether they were a kind of Eal or Leech.

I ſhall add no other obſervations made on this minute Animal, being prevented herein by many excellent ones already publiſh'd by the ingenious, Doctor *Power*, among his *Microſcopical* Obſervations, ſave onely that a quantity of Vinegar repleat with them being included in a ſmall Viol, and ſtop'd very cloſe from the ambient air, all the included Worms in a very ſhort time died, as if they had been ſtifled.

And that their motion ſeems (contrary to what we may obſerve in the motion of all other Inſects) exceeding ſlow. But the reaſon of it ſeems plain, for being to move to and fro after that manner which they do, by waving onely, or wrigling their body; the tenacity, or glutinouſneſs, and the denſity or reſiſtance of the fluid *medium* becomes ſo exceeding ſenſible to their extremely minute bodies, that it is to me indeed a greater wonder that they move them ſo faſt as they do, then that they move them no faſter. For what a vaſtly greater proportion have they of their ſuperficies to their bulk, then Eels or other larger Fiſhes, and next, the tenacity and denſity of the liquor being much the ſame to be moved, both by the one and the other, the reſiſtance or impediment thence ariſing to the motions made through it, muſt be almoſt infinitely greater to the ſmall one then to the great. This we find experimentally verify'd in the Air, which though a *medium* a thouſand times more rarify'd then the water, the reſiſtance of it to motions made through it, is yet ſo ſenſible to very minute bodies, that a Down-feather (the leaſt of whoſe parts ſeem yet bigger then theſe Eels, and many of them almoſt incomparably bigger, ſuch as the quill and ſtalk) is ſuſpended by it, and carried to and fro as if it had no weight.

Obſerv. LVIII. *Of a new Property in the* Air, *and ſeveral other tranſparent* Mediums *nam'd* Inflection, *whereby very many conſiderable* Phænomena *are attempted to be ſolv'd, and divers other uſes are hinted.*

Since the Invention (and perfecting in ſome meaſure) of *Teleſcopes*, it has been obſerv'd by ſeveral, that the Sun and Moon neer the Horizon, are disfigur'd (loſing that exactly-ſmooth terminating circular limb, which they are obſerv'd to have when ſituated neerer the Zenith) and are bounded with an edge every way (eſpecially upon the right and left

ſides) ragged and indented like a Saw: which inequality of their limbs, I have further obſerv'd, not to remain always the ſame, but to be continually chang'd by a kind of fluctuating motion, not unlike that of the waves of the Sea; ſo as that part of the limb, which was but even now nick'd or indented in, is now protuberant, and will preſently be ſinking again; neither is this all, but the whole body of the Luminaries, do in the *Teleſcope*, ſeem to be depreſs'd and flatted, the upper, and more eſpecially the under ſide appearing neerer to the middle then really they are, and the right and left appearing more remote: whence the whole *Area* ſeems to be terminated by a kind of Oval. It is further obſerv'd, that the body, for the moſt part, appears red, or of ſome colour approaching neer unto it, as ſome kind of yellow; and this I have always mark'd, that the more the limb is flatted or ovalled, the more red does the body appear, though not always the contrary. It is further obſervable, that both fix'd Stars and Planets, the neerer they appear to the Horizon, the more red and dull they look, and the more they are obſerv'd to twinkle; in ſo much, that I have ſeen the Dog-ſtarr to vibrate ſo ſtrong and bright a radiation of light, as almoſt to dazle my eyes, and preſently, almoſt to diſappear. It is alſo obſervable, that thoſe bright ſcintillations neer the Horizon, are not by much ſo quick and ſudden in their conſecutions of one another, as the nimbler twinklings of Stars neerer the Zenith. This is alſo notable, that the Starrs neer the Horizon, are twinkled with ſeveral colours; ſo as ſometimes to appear red, ſometimes more yellow, and ſometimes blue, and this when the Starr is a pretty way elevated above the Horizon. I have further, very often ſeen ſome of the ſmall Starrs of the fifth or ſixth magnitude, at certain times to diſappear for a ſmall moment of time, and again appear more conſpicuous, and with a greater luſter. I have ſeveral times, with my naked eye, ſeen many ſmaller Starrs, ſuch as may be call'd of the ſeventh or eighth magnitude to appear for a ſhort ſpace, and then vaniſh, which, by directing a ſmall *Teleſcope* towards that part they appear'd and diſappeard in; I could preſently find to be indeed ſmall Starrs ſo ſituate, as I had ſeen them with my naked eye, and to appear twinkling like the ordinary viſible Stars; nay, in examining ſome very notable parts of the Heaven, with a three foot Tube, me thought I now and then, in ſeveral parts of the conſtellation, could perceive little twinklings of Starrs, making a very ſhort kind of apparition, and preſently vaniſhing, but noting diligently the places where they thus ſeem'd to play at boe-peep, I made uſe of a very good twelve foot Tube, and with that it was not uneaſie to ſee thoſe, and ſeveral other degrees of ſmaller Starrs, and ſome ſmaller yet, that ſeem'd again to appear and diſappear, and theſe alſo by giving the ſame Object-glaſs a much bigger aperture, I could plainly and conſtantly ſee appear in their former places; ſo that I have obſerv'd ſome twelve ſeveral magnitudes of Starrs leſs then thoſe of the ſix magnitudes commonly recounted in the Globes.

It has been obſerv'd and confirm'd by the accurateſt Obſervations of the beſt of our modern Aſtronomers, that all the Luminous bodies appear above the Horizon, when they really are below it. So that the

Sun

Sun and Moon have both been ſeen above the Horizon, whil'ſt the Moon has been in an Eclipſe. I ſhall not here inſtance in the great refractions, that the tops of high mountains, ſeen at a diſtance, have been found to have; all which ſeem to argue the Horizontal refraction, much greater then it is hitherto generally believ'd.

I have further taken notice, that not onely the Sun, Moon and Starrs, and high tops of mountains have ſuffer'd theſe kinds of refraction, but Trees, and ſeveral bright Objects on the ground: I have often taken notice of the twinkling of the reflections of the Sun from a Glaſs-window at a good diſtance, and of a Candle in the night, but that is not ſo conſpicuous and in obſerving the ſetting Sun, I have often taken notice of the tremulation of the Trees and Buſhes, as well as of the edges of the Sun. Divers of theſe *Phænomena* have been taken notice of by ſeveral, who have given ſeveral reaſons of them, but I have not yet met with any altogether ſatisfactory, though ſome of their conjectures have been partly true, but parly alſo falſe. Setting my ſelf therfore upon the inquiry of theſe *Phænomena*, I firſt endeavour'd to be very diligent in taking notice of the ſeveral particulars and circumſtances obſervable in them; and next, in making divers particular Experiments, that might cleer ſome doubts, and ſerve to determine, confirm, and illuſtrate the true and adæquate cauſe of each; and upon the whole, I find much reaſon to think, that the true cauſe of all theſe *Phænomena* is from the *inflection*, or *multiplicate refraction* of thoſe Rays of light within the body of the *Atmoſphere*, and that it does not proceed from a *refraction* caus'd by any terminating *ſuperficies* of the Air above, nor from any ſuch exactly defin'd *ſuperficies* within the body of the *Atmoſphere*.

This Concluſion is grounded upon theſe two Propoſitions:

Firſt, that a *medium*, whoſe parts are unequally *denſe*, and mov'd by various motions and tranſpoſitions as to one another, will produce all theſe viſible effects upon the Rays of light, without any other *coefficient* cauſe.

Secondly, that there is in the Air or *Atmoſphere*, ſuch a variety in the conſtituent parts of it, both as to their *denſity* and *rarity*, and as to their divers mutations and poſitions one to another.

By *Denſity* and *Rarity*, I underſtand a property of a tranſparent body, that does either more or leſs refract a Ray of light (coming obliquely upon its ſuperficies out of a third *medium*) toward its perpendicular: As I call Glaſs a more denſe body then Water, and Water a more rare body then Glaſs, becauſe of the refractions (more or leſs deflecting towards the perpendicular) that are made in them, of a Ray of light out of the Air that has the ſame inclination upon either of their ſuperficies.

So as to the buſineſs of Refraction, ſpirit of Wine is a more *denſe* body then Water, it having been found by an accurate Inſtrument that meaſures the angles of Refractions to Minutes that for the ſame refracted angle of 30: 00′ in both thoſe *Mediums*, the angle of incidence in Water was but 41°. 35. but the angle of the incidence in the trial with ſpirit of Wine was 42°: 45′. But as to gravity, Water is a more *denſe* body then

ſpirit of Wine, for the proportion of the ſame Water, to the ſame very well rectify'd ſpirit of Wine was, as 21. to 19.

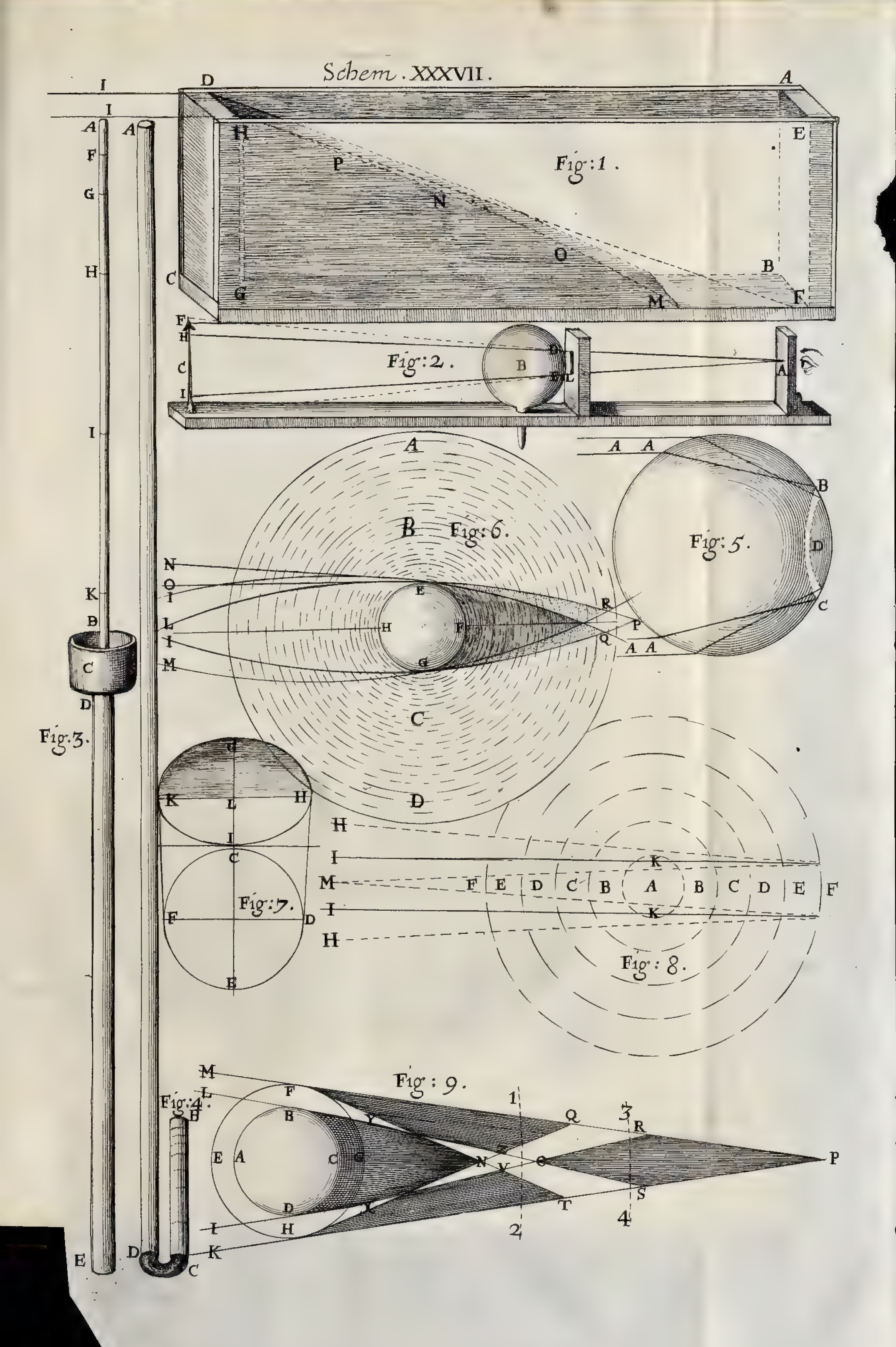
So as to Refraction, Water is more Denſe then Ice; for I have found by a moſt certain Experiment, which I exhibited before divers illuſtrious Perſons of the *Royal Society*, that the Refraction of Water was greater then that of Ice, though ſome conſiderable Authors have affirm'd the contrary, and though the Ice be a very hard, and the Water a very fluid body.

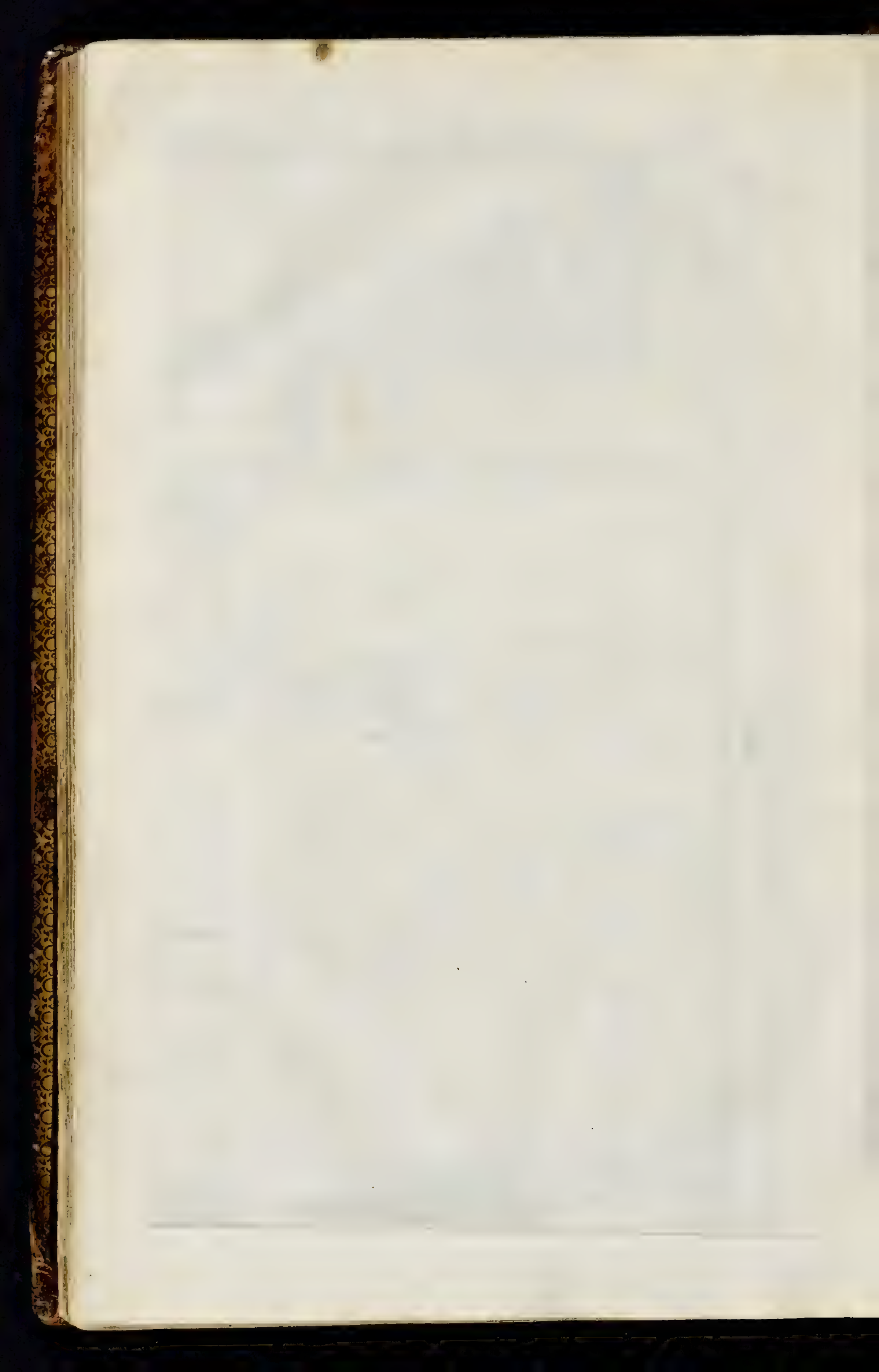
That the former of the two preceding Propoſitions is true, may be maniſeſted by ſeveral Experiments: As firſt, if you take any two liquors differing from one another in denſity, but yet ſuch as will readily mix: as Salt Water, or Brine, & Freſh; almoſt any kind of Salt diſſolv'd in Water, and filtrated, ſo that it be cleer, ſpirit of Wine and Water; nay, ſpirit of Wine, and ſpirit of Wine, one more highly rectify'd then the other, and very many other liquors; if (I ſay) you take any two of theſe liquors, and mixing them in a Glaſs Viol, againſt one ſide of which you have fix'd or glued a ſmall round piece of Paper, and ſhaking them well together (ſo that the parts of them may be ſomewhat diſturb'd and move up and down) you endeavour to ſee that round piece of Paper through the body of the liquors; you ſhall plainly perceive the Figure to wave, and to be indented much after the ſame manner as the limb of the Sun through a *Teleſcope* ſeems to be, ſave onely that the mutations here, are much quicker. And if, in ſteed of this bigger Circle, you take a very ſmall ſpot, and faſten and view it as the former, you will find it to appear much like the twinkling of the Starrs, though much quicker: which two *Phænomena* (for I ſhall take notice of no more at preſent, though I could inſtance in multitudes of others) muſt neceſſarily be caus'd by an *inflection* of the Rays within the terminating ſuperficies of the compounded *medium*, ſince the ſurfaces of the tranſparent body through which the Rays paſs to the eye, are not at all altered or chang'd.

This *inflection* (if I may ſo call it) I imagine to be nothing elſe, but a *multiplicate refraction*, cauſed by the unequal *denſity* of the conſtituent parts of the *medium*, whereby the motion, action or progreſs of the Ray of light is hindred from proceeding in a ſtreight line, and *inflected* or *deflected* by a *curve*. Now, that it is a *curve* line is maniſeſt by this Experiment: I took a Box, ſuch as A D G E, in the firſt *Figure* of the 37. *Scheme*, whoſe ſides A B C D, and E F G H, were made of two ſmooth flat plates of Glaſs, then filling it half full with a very ſtrong ſolution of Salt, I filled the other half with very fair freſh water, then expoſing the opacous ſide, D H G C, to the Sun, I obſerv'd both the *refraction* and *inflection* of the Sun beams, I D & K H, and marking as exactly as I could, the points, P, N, O, M, by which the Ray, K H, paſſed through the compounded *medium*, I found them to be in a *curve* line; for the parts of the *medium* being continually more denſe the neerer they were to the bottom, the Ray *p f* was continually more and more deflected downwards from the ſtreight line.

This Inflection may be mechanically explained, either by Monſieur

Des


Fig: 1.
Fig: 2.
Fig. 3.
Fig: 4.
Fig: 5.
Fig: 6.
Fig: 7.
Fig: 8.
Fig: 9.



Des Cartes principles, by conceiving the Globuls of the third Element to find less and less resistance against that side of them which is downwards, or by a way, which I have further explicated in the Inquisition about Colours, to be from an obliquation of the pulse of light, whence the ruder part is continually promoted, and consequently refracted towards the perpendicular, which cuts the Orbs at right angles. What the particular Figure of the *Curve line*, describ'd by this way of light, is, I shall not now stand to examine, especially since there may be so many sorts of it as there may be varieties of the Positions of the *intermediat* degrees of *density* and *rarity* between the bottom and the top of the inflecting Medium.

I could produce many more Examples and Experiments, to illustrate and prove this first Proposition, *viz.* that there is such a constitution of some bodies as will cause inflection. As not to mention those I have observ'd in *Horn*, *Tortoise-shell*, *transparent Gums*, and *resinous Substances*: The *veins* of Glass, nay, of melted *Crystal*, found, and much complained of by Glass-grinders, and others, might sufficiently demonstrate the truth of it to any diligent Observator.

But that, I presume, I have by this Example given proof sufficient (*viz. ocular demonstration*) to evince, that there is such a modulation, or bending of the rayes of light, as I have call'd *inflection*, differing both from *reflection*, and *refraction* (since they are both made in the superficies, this only in the middle); and likewise, that this is able or sufficient to produce the effects I have ascribed to it.

It remains therefore to shew, that there is such a property in the Air, and that it is sufficient to produce all the above mentioned *Phænomena*, and therefore may be the principal, if not the only cause of them.

First, That there is such a property, may be proved from this, that the parts of the Air are some of them more condens'd, others more rarified, either by the differing heat, or differing pressure it sustains, or by the somewhat heterogeneous vapours intersper'd through it. For as the Air is more or less rarified, so does it more or less refract a ray of light (that comes out of a denser medium) from the perpendicular. This you may find true, if you make tryal of this Experiment.

Take a small Glass-bubble, made in the form of that in the second Figure of the 37. *Scheme*, and by heating the Glass very hot, and thereby very much rarifying the included Air, or, which is better, by rarifying a small quantity of water, included in it, into vapours, which will expel the most part, if not all the Air, and then sealing up the small neck of it, and letting it cool, you may find, if you place it in a convenient Instrument, that there will be a manifest difference, as to the refraction.

As if in this second Figure you suppose A to represent a small sight or hole, through which the eye looks upon an object, as C, through the Glass-bubble B, and the second sight L; all which remain exactly fixt in their several places, the object C being so cized and placed, that it may just seem to touch the upper and under edge of the hole L: and so all of it be seen through the small Glass-ball of rarified Air; then by

breaking

breaking off the ſmall ſeal'd neck of the Bubble (without at all ſtirring the ſights, object, or glaſs) and admitting the external Air, you will find your ſelf unable to ſee the utmoſt ends of the object; but the terminating rayes A E and A D (which were before refracted to G and F by the rarified Air) will proceed almoſt directly to I and H; which alteration of the rayes (ſeeing there is no other alteration made in the Organ by which the Experiment is tryed, ſave only the admiſſion, or excluſion of the condens'd Air) muſt neceſſarily be cauſed by the variation of the *medium* contain'd in the Glaſs B; the greateſt difficulty in the making of which Experiment, is from the uneven ſurfaces of the bubble, which will repreſent an uneven image of the object.

Now, that there is ſuch a difference of the upper and under parts of the Air, is clear enough evinc'd from the late improvement of the *Torricellian* Experiment, which has been tryed at the tops and feet of Mountains; and may be further illuſtrated, and inquired into, by a means, which ſome whiles ſince I thought of, and us'd, for the finding by what degrees the Air paſſes from ſuch a degree of Denſity to ſuch a degree of Rarity. And another, for the finding what preſſure was requiſite to make it paſs from ſuch a degree of Rarefaction to a determinate Denſity: Which Experiments, becauſe they may be uſeful to illuſtrate the preſent Inquiry, I ſhall briefly deſcribe.

Fig. 3.

I took then a ſmall Glaſs-pipe A B, about the bigneſs of a Swans quill, and about four foot long, which was very equally drawn, ſo that, as far as I could perceive, no one part was bigger then another: This Tube (being open at both ends) I fitted into another ſmall Tube D E, that had a ſmall bore juſt big enough to contain the ſmall Pipe, and this was ſeal'd up at one, and open at the other, end; about which open end I faſtned a ſmall wooden box C with cement, ſo that filling the bigger Tube, and part of the box, with Quickſilver, I could thruſt the ſmaller Tube into it, till it were all covered with the Quickſilver: Having thus done, I faſtned my bigger Tube againſt the ſide of a wall, that it might ſtand the ſteadier, and plunging the ſmall Tube cleer under the *Mercury* in the box, I ſtopt the upper end of it very faſt with cement, then lifting up the ſmall Tube, I drew it up by a ſmall pully, and a ſtring that I had faſtned to the top of the Room, and found the height of the *Mercurial Cylinder* to be about twenty nine inches.

Then letting down the Tube again, I opened the top, and then thruſt down the ſmall Tube, till I perceived the Quickſilver to riſe within it to a mark that I had plac'd juſt an inch from the top; and immediately clapping on a ſmall peice of cement that I had kept warm, I with a hot Iron ſeal'd up the top very faſt, then letting it cool (that both the cement might grow hard, and more eſpecially, that the Air might come to its temper, natural for the Day I try'd the Experiment in) I obſerv'd diligently, and found the included Air to be exactly an Inch.

Here you are to take notice, that after the Air is ſeal'd up, the top of the Tube is not to be elevated above the ſuperficies of the Quickſilver

in

in the box, till the surface of that within the Tube be equal to it, for the Quickfilver (as I have elsewhere prov'd) being more heterogeneous to the Glafs then the Air, will not naturally rife up fo high within the fmall Pipe,as the fuperficies of the *Mercury* in the box ; and therefore you are to obferve, how much below the outward fuperficies of the *Mercury* in the box, that of the fame in the Tube does ftand, when the top being open, free ingrefs is admitted to the outward Air.

Having thus done, I permitted the *Cylinder*, or fmall Pipe, to rife out of the box, till I found the furface of the Quickfilver in the Pipe to be two inches above that in the box, and found the Air to have expanded it felf but one fixteenth part of an inch ; then drawing up the fmall pipe, till I found the height of the Quickfilver within to be four inches above that without, I obferved the Air to be expanded only $\frac{1}{7}$ of an inch more then it was at firft, and to take up the room of $1\frac{1}{7}$ inch : then I raifed the Tube till the Cylinder was fix inches high, and found the Air to take up $1\frac{2}{9}$ inches of room in the Pipe ; then to 8, 10, 12. *&c.* the expanfion of the Air that I found to each of which Cylinders are fet down in the following Table ; where the firft row fignifies the height of the *Mercurial Cylinder* ; the next, the expanfion of the Air ; the third, the preffure of the *Atmofphere*, or the higheft *Cylinder* of *Mercury*, which was then neer thirty inches ; The laft fignifies the force of the Air fo expanded, which is found by fubftracting the firft row of numbers out of the third ; for having found, that the outward Air would then keep up the Quickfilver to thirty inches, look whatever of that height is wanting muft be attributed to the Elater of the Air depreffing. And therefore having the Expanfion in the fecond row,and the height of the fubjacent *Cylinder* of *Mercury* in the firft, and the greateft height of the *Cylinder* of *Mercury*, which of it felf counterballances the whole preffure of the *Atmofphere* ; by fubftracting the numbers of the firft row out of the numbers of the third, you will have the meafure of the *Cylinders* fo depreft, and confequently the force of the Air,in the feveral Expanfions, regiftred.

The

The height of the Cylinder of *Mercury*, that, together with the Elater of the included Air, ballanced the pressure of the Atmosphere.	The Expansion of the Air.	The height of the *Mercury* that counter-ballanc'd the Atmosphere	The strength of the Elater of the expanded Air.
00	01	30	30
02	01 $\frac{1}{16}$	30	28
04	01 $\frac{1}{7}$	30	26
06	01 $\frac{2}{9}$	30	24
08	01 $\frac{1}{3}$	30	22
10	01 $\frac{1}{2}$	30	20
12	01 $\frac{2}{3}$	30	18
14	01 $\frac{5}{6}$	30	16
16	02 $\frac{2}{27}$	30	14
18	02 $\frac{4}{9}$	30	12
20	03	30	10
22	03 $\frac{7}{9}$	30	8
24	05 $\frac{7}{18}$	30	6
25	06 $\frac{2}{3}$	30	5
26	08 $\frac{1}{2}$	30	4
26 $\frac{1}{4}$	09 $\frac{1}{2}$	30	3 $\frac{3}{4}$
26 $\frac{1}{2}$	10 $\frac{3}{4}$	30	3 $\frac{1}{2}$
26 $\frac{3}{4}$	13	30	3 $\frac{1}{4}$
27	15 $\frac{1}{2}$	30	3

I had ſeveral other Tables of my Obſervations, and Calculations, which I then made; but it being above a twelve month ſince I made them; and by that means having forgot many circumſtances and particulars, I was reſolved to make them over once again, which I did *Auguſt* the ſecond 1661. with the very ſame Tube which I uſed the year before, when I firſt made the Experiment (for it being a very good one, I had carefully preſerv'd it:) And after having tryed it over and over again; and being not well ſatisfied of ſome particulars, I, at laſt, having put all things in very good order, and being as attentive, and obſervant, as poſſibly I could, of every circumſtance requiſite to be taken notice of, did regiſter my ſeveral Obſervations in this following Table. In the making of which, I did not exactly follow the method that I had uſed at firſt; but, having lately heard of Mr. *Townly's Hypotheſis*, I ſhap'd my courſe in ſuch ſort, as would be moſt convenient for the examination of that *Hypotheſis*; the event of which you have in the latter part of the laſt Table.

The other Experiment was, to find what degrees of force were requiſite to compreſs, or condenſe, the Air into ſuch or ſuch a bulk.

The manner of proceeding therein was this: I took a Tube about five foot long, one of whoſe ends was ſealed up, and bended in the form of a *Syphon*, much like that repreſented in the fourth Figure of the 37. *Scheme*, one ſide whereof A D, that was open at A, was about fifty inches long, the other ſide B C, ſhut at B, was not much above ſeven inches long; then placing it exactly perpendicular, I pour'd in a little Quickſilver, and found that the Air B C was $6\frac{7}{8}$ inches, or very near to ſeven; then pouring in Quickſilver at the longer Tube, I continued filling of it till the Air in the ſhorter part of it was contracted into half the former dimenſions, and found the height exactly nine and twenty inches; and by making ſeveral other tryals, in ſeveral other degrees of condenſation of the Air, I found them exactly anſwer the former *Hypotheſis*.

But having (by reaſon it was a good while ſince I firſt made) forgotten many particulars, and being much unſatisfied in others, I made the Experiment over again, and, from the ſeveral tryals, collected the former part of the following Table: Where in the row next the left hand 24. ſignifies the dimenſions of the Air, ſuſtaining only the preſſure of the *Atmoſphere*, which at that time was equal to a *Cylinder* of *Mercury* of nine and twenty inches: The next Figure above it (20) was the dimenſions of the Air induring the firſt compreſſion, made by a *Cylinder* of *Mercury* $5\frac{1}{16}$ high, to which the preſſure of the *Atmoſphere* nine and twenty inches being added, the elaſtick ſtrength of the Air ſo compreſt will be found $34\frac{1}{16}$, &c.

A Table of the Elaſtick power of the Air, both Experimentally and Hypothetically calculated, according to its various Dimenſions.

The dimenſions of the included Air.	The height of the *Mercurial Cylinder* counterpois'd by the *Atmoſphere.*	The *Mercurial Cylinder* added, or taken from the former.	The ſum or difference of theſe two *Cylinders.*	What they ought to be according to the *Hypotheſis.*
12	29 +	29 =	58	58
13	29 +	$24\frac{11}{16}$ =	$53\frac{11}{16}$	$53\frac{7}{13}$
14	29 +	$20\frac{3}{16}$ =	$49\frac{3}{16}$	$49\frac{5}{7}$
16	29 +	14 =	43	$43\frac{1}{2}$
18	29 +	$9\frac{1}{8}$ =	$38\frac{1}{8}$	$38\frac{2}{3}$
20	29 +	$5\frac{3}{16}$ =	$34\frac{3}{16}$	$34\frac{4}{5}$
24	29	0 =	29	29
48	29 —	$14\frac{5}{8}$ =	$14\frac{3}{8}$	$14\frac{1}{2}$
96	29 —	$22\frac{1}{8}$ =	$6\frac{7}{8}$	$7\frac{1}{8}$
192	20 —	$25\frac{5}{8}$ =	$3\frac{3}{8}$	$3\frac{5}{8}$
384	29 —	$27\frac{2}{8}$ =	$1\frac{6}{8}$	$1\frac{7}{16}$
576	29 —	$27\frac{7}{8}$ =	$1\frac{1}{8}$	$1\frac{5}{24}$
768	29 —	$28\frac{1}{8}$ =	$0\frac{7}{8}$	$0\frac{7\frac{1}{4}}{8}$
960	29 —	$28\frac{3}{8}$ =	$0\frac{5}{8}$	$0\frac{5\frac{4}{5}}{8}$
1152	29 —	$28\frac{7}{16}$ =	$0\frac{9}{16}$	$0\frac{10}{16}$

From

From which Experiments, I think, we may ſafely conclude, that the Elater of the Air is reciprocal to its extenſion, or at leaſt very neer. So that to apply it to our preſent purpoſe (which was indeed the chief cauſe of inventing theſe wayes of tryal) we will ſuppoſe a *Cylinder* indefinitely extended upwards, [I ſay a *Cylinder*, not a piece of a *Cone*, becauſe, as I may elſewhere ſhew in the Explication of Gravity, that *triplicate* proportion of the ſhels of a Sphere, to their reſpective diameters, I ſuppoſe to be removed in this caſe by the decreaſe of the power of Gravity] and the preſſure of the Air at the bottom of this *Cylinder* to be ſtrong enough to keep up a *Cylinder* of *Mercury* of thirty inches: Now becauſe by the moſt accurate tryals of the moſt illuſtrious and incomparable Mr. *Boyle*, publiſhed in his deſervedly famous Pneumatick Book, the weight of Quickſilver, to that of the Air here below, is found neer about as fourteen thouſand to one: If we ſuppoſe the parts of the *Cylinder* of the *Atmoſphere* to be every where of an equal denſity, we ſhall (as he there deduces) find it extended to the height of thirty five thouſand feet, or ſeven miles: But becauſe by theſe Experiments we have ſomewhat confirm'd the hypotheſis of the reciprocal proportion of the Elaters to the Extenſions we ſhall find, that by ſuppoſing this *Cylinder* of the *Atmoſphere* divided into a thouſand parts, each of which being equivalent to thirty five feet, or ſeven geometrical paces, that is, each of theſe diviſions containing as much Air as is ſuppos'd in a *Cylinder* neer the earth of equal diameter, and thirty five foot high, we ſhall find the lowermoſt to preſs againſt the ſurface of the Earth with the whole weight of the above mentioned thouſand parts; the preſſure of the bottom of the ſecond againſt the top of the firſt to be 1000—1=999. of the third againſt the ſecond to be 1000—2=998. of the fourth againſt the third to be 1000—3=997. of the uppermoſt againſt the 999. or that next below it, to be 1000—999=1. ſo that the extenſion of the lowermoſt next the Earth, will be to the extenſion of the next below the uppermoſt, as 1. to 999. for as the preſſure ſuſtained by the 999. is to the preſſure ſuſtain'd by the firſt, ſo is the extenſion of the firſt to the extenſion of the 999. ſo that, from this hypothetical calculation, we ſhall find the Air to be indefinitely extended: For if we ſuppoſe the whole thickneſs of the Air to be divided, as I juſt now inſtanced, into a thouſand parts, and each of thoſe under differing Dimenſions, or Altitudes, to contain an equall quantity of Air, we ſhall find, that the firſt *Cylinder*, whoſe Baſe is ſuppoſed to lean on the Earth, will be found to be extended $35\frac{35}{999}$ foot; the ſecond equal Diviſion, or *Cylinder*, whoſe *baſis* is ſuppoſed to lean on the top of the firſt, ſhall have its top extended higher by $35\frac{70}{998}$; the third $35\frac{105}{997}$; the fourth $35\frac{140}{996}$; and ſo onward, each equal quantity of Air having its dimenſions meaſured by 35. and ſome additional number expreſt alwayes in the manner of a fraction, whoſe numerator is alway the number of the place multipli'd by 35. and whoſe denominator is alwayes the preſſure of the *Atmoſphere* ſuſtain'd by that part, ſo that by this means we may eaſily calculate the height of 999. diviſions of thoſe 1000. diviſions, I ſuppos'd; whereas the uppermoſt

may extend it ſelf more then as high again,nay, perhaps indefinitely, or beyond the Moon ; for the Elaters and Expanſions being in reciprocal proportions,ſince we cannot yet find the *plus ultra*, beyond which the Air will not expand it ſelf, we cannot determine the height of the Air : for ſince, as we have ſhewn, the proportion will be alway as the preſſure ſuſtain'd by any part is to 35. ſo 1000. to the expanſion of that part ; the multiplication or product therefore of the preſſure, and expanſion, that is, of the two extream proportionals, being alwayes equal to the product of the means, or 35000. it follows, ſince that Rectangle or Product may be made up of the multiplication of infinite diverſities of numbers, that the height of the Air is alſo indefinite ; for ſince (as far as I have yet been able to try) the Air ſeems capable of an indefinite Expanſion, the preſſure may be decreaſed in *infinitum*, and conſequently its expanſion upwards indefinite alſo.

There being therefore ſuch a difference of denſity, and no Experiment yet known to prove a *Saltus*, or ſkipping from one degree of rarity to another much differing from it, that is, that an upper part of the Air ſhould ſo much differ from that immediately *ſubjacent* to it, as to make a diſtinct ſuperficies, ſuch as we obſerve between the Air and Water, *&c.* But it being more likely, that there is a continual increaſe of rarity in the parts of the Air, the further they are removed from the ſurface of the Earth : It will hence neceſſarily follow, that (as in the Experiment of the ſalt and freſh Water) the ray of Light paſſing obliquely through the Air alſo, which is of very different denſity, will be continually, and infinitely inflected, or bended, from a ſtreight, or direct motion.

This granted, the reaſon of all the above recited *Phænomena*, concerning the appearance of the Celeſtial Bodies, will very eaſily be deduced. As,

Firſt, The redneſs of the Sun, Moon, and Stars, will be found to be cauſed by the inflection of the rays within the *Atmoſphere*. That it is not really in or near the luminous bodies, will, I ſuppoſe, be very eaſily granted, ſeeing that this redneſs is obſervable in ſeveral places differing in Longitude, to be at the ſame time different, the ſetting and riſing Sun of all parts being for the moſt part red,

And ſecondly, That it is not meerly the colour of the Air interpos'd, will, I ſuppoſe, without much more difficulty be yielded, ſeeing that we may obſerve a very great *interſtitium* of Air betwixt the Object and the Eye, makes it appear of a dead blew, far enough differing from a red, or yellow.

But thirdly, That it proceeds from the refraction,or inflection, of the rays by the *Atmoſphere*, this following Experiment will, I ſuppoſe, ſufficiently manifeſt.

Take a ſphærical Cryſtalline Viol, ſuch as is deſcrib'd in the fifth Figure A B C D, and, having fill'd it with pure clear Water, expoſe it to the Sun beams ; then taking a piece of very fine *Venice* Paper, apply it againſt that ſide of the Globe that is oppoſite to the Sun, as againſt the ſide

ſide B C, and you ſhall perceive a bright red Ring to appear, cauſ'd by the refraction of the Rays, A A A A, which is made by the Globe; in which Experiment, if the Glaſs and Water be very cleer, ſo that there be no Sands nor bubbles in the Glaſs, nor dirt in the Water, you ſhall not perceive any appearance of any other colour. To apply which Experiment, we may imagine the *Atmoſphere* to be a great tranſparent Globe, which being of a ſubſtance more denſe then the other, or (which comes to the ſame) that has its parts more denſe towards the middle, the Sun beams that are tangents, or next within the tangents of this Globe, will be refracted or inflected from their direct paſſage towards the center of the Globe, whence, according to the laws of refractions made in a triangular *Priſm*, and the generation of colour ſet down in the deſcription of Muſcovi-glaſs, there muſt neceſſarily appear a red colour in the *tranſitus* or paſſage of thoſe tangent Rays. To make this more plain, we will ſuppoſe (in the ſixth *Figure*) A B C D, to repreſent the Globe of the *Atmoſphere*, E F G H to repreſent the opacous Globe of the Earth, lying in the midſt of it, neer to which, the parts of the Air ſuſtaining a very great preſſure, are thereby very much condens'd, from whence thoſe Rays that are by inflection made tangents to the Globe of the Earth, and thoſe without them, that paſs through the more condens'd part of the *Atmoſphere*, as ſuppoſe between A and E, are by reaſon of the inequality of the *medium*, inflected towards the center, whereby there muſt neceſſarily be generated a red colour, as is more plainly ſhewn in the former cited place; hence whatſoever opacous bodies (as vapours, or the like) ſhall chance to be elevated into thoſe parts, will reflect a red towards the eye; and therefore thoſe evenings and mornings appear reddeſt, that have the moſt ſtore of vapours and halituous ſubſtances exhaled to a convenient diſtance from the Earth; for thereby the inflection is made the greater, and thereby the colour alſo the more intenſe; and ſeveral of thoſe exhalations being opacous, reflect ſeveral of thoſe Rays, which, through an *Homogeneous* tranſparent *medium* would paſs unſeen; and therefore we ſee, that when there chances to be any clouds ſituated in thoſe Regions they reflect a ſtrong and vivid red. Now, though one great cauſe of the redneſs may be this inflection, yet I cannot wholly exclude the colour of the vapours themſelves, which may have ſomething of redneſs in them, they being partly nitrous, and partly fuliginous; both which ſteams tinge the Rays that paſs through them, as is made evident by looking at bodies through the fumes of *Aqua fortis*, or ſpirit of *Nitre* [as the newly mentioned Illuſtrious Perſon has demonſtrated] and alſo through the ſmoak of a Fire or Chimney.

Having therefore made it probable at leaſt, that the morning and evening redneſs may partly proceed from this inflection or refraction of the Rays, we ſhall next ſhew, how the Oval Figure will be likewiſe eaſily deduced.

Suppoſe we therefore, E F G H in the ſixth *Figure* of the 37. *Scheme*, to repreſent the Earth; A B C D, the *Atmoſpere*; E I, and E L, two Rays coming from the Sun, the one from the upper, the other from the neather

Limb,

Limb, these Rays, being by the *Atmosphere* inflected, appear to the ... at E, as if they had come from the points, N and O; and because the Ray L has a greater inclination upon the inequality of the *Atmosphere* then I, therefore must it suffer a greater inflection, and consequently be further elevated above its true place, then the Ray I, which has a less inclination, will be elevated above its true place; whence it will follow, that the lower side appearing neerer the upper then really it is, and the two *lateral* sides, *viz.* the right and left side, suffering no sensible alteration from the inflection, at least what it does suffer, does rather increase the visible Diameter then diminish it, as I shall shew by and by, the Figure of the luminous body must necessarily appear somewhat *Elliptical.*

This will be more plain, if in the seventh *Figure* of th 37. *Scheme* we suppose A B to represent the sensible Horizon; C D E F, the body of the Sun really below it; G H I K, the same appearing above it, elevated by the inflection of the *Atmosphere*: For if, according to the best observation, we make the visible Diameter of the Sun to be about three or four and thirty minutes,and the Horizontal refraction according to *Ticho* be thereabout,or somewhat more,the lower limb of the Sun E,will be elevated to I; but because,by his account, the point C will be elevated but 29. minutes, as having not so great an inclination upon the inequality of the Air, therefore I G, which will be the apparent refracted perpendicular Diameter of the Sun,will be less then C G,which is but29. minutes,and consequently six or seven minutes shorter then the unrefracted apparent Diameter. The parts, D and F, will be likewise elevated to H and K, whose refraction, by reason of its inclination, will be bigger then that of the point C,though less then that of E;therefore will the semidiameter I L, be shorter then L G, and consequently the under side of the appearing Sun more flat then the upper.

Now, because the Rays from the right and left sides of the Sun, *&c.* have been observ'd by *Ricciolo* and *Grimaldus*, to appear more distant one from another then really they are,though(by very manyObservations that I have made for that purpose,with a very good *Telescope*,fitted with a divided Ruler) I could never perceive any great alteration, yet there being really some,it will not be amiss,to shew that this also proceeds from the refraction or inflection of the *Atmosphere*; and this will be manifest,if we consider the *Atmosphere* as a transparent Globe, or at least a transparent shell, encompassing an opacous Globe,which, being more dense then the *medium* encompassing it, refracts or inflects all the entring parallel Rays into a point or focus,so that wheresoever the Observator is plac'd within the *Atmosphere*, between the focus and the luminous body, the *lateral* Rays must necessarily be more converg'd towards his eye by the refraction or inflection, then they would have been without it; and therefore the Horizontal Diameter of the luminous body must necessarily be augmented.

This might be more plainly manifest to the eye by the sixth *Figure*; but because it would be somwhat tedious, and the thing being obvious enough

enough to be imagin'd by any one that attentively considers it, I shall rather omit it, and proceed to shew, that the mass of Air neer the surface of the Earth, consists, or is made up, of parcels, which do very much differ from one another in point of density and rarity; and consequently the Rays of light that pass through them will be variously inflected, here one way, and there another, according as they pass so or so through those differing parts; and those parts being always in motion, either upwards or downwards, or to the right or left, or in some way compounded of these, they do by this their motion inflect the Rays, now this way, and presently that way.

This irregular, unequal and unconstant inflection of the Rays of light, is the reason why the limb of the *Sun*, *Moon*, *Jupiter*, *Saturn*, *Mars*, and *Venus*, appear to wave or dance; and why the body of the Starrs appear to tremulate or twinkle, their bodies, by this means, being sometimes magnify'd, and sometimes diminished; sometimes elevated, otherwhiles depress'd; now thrown to the right hand, and then to the left.

And that there is such a property or unequal distribution of parts, is manifest from the various degrees of heat and cold that are found in the Air; from whence will follow a differing density and rarity, both as to quantity and refraction; and likewise from the vapours that are interpos'd, (which, by the way, I imagine, as to refraction or inflection, to do the same thing, as if they were rarify'd Air; and that those vapours that ascend, are both lighter, and less dense, then the ambient Air which boys them up; and that those which descend, are heavier and more dense) The first of these may be found true, if you take a good thick piece of Glass, and heating it pretty hot in the fire, lay it upon such another piece of Glass, or hang it in the open Air by a piece of Wire, then looking upon some far distant Object (such as a Steeple or Tree) so as the Rays from that Object pass directly over the Glass before they enter your eye, you shall find such a tremulation and wavering of the remote Object, as will very much offend your eye: The like tremulous motion you may observe to be caus'd by the ascending steams of Water, and the like. Now, from the first of these it is manifest, that from the rarifaction of the parts of the Air, by heat, there is caus'd a differing refraction, and from the ascension of the more rarify'd parts of the Air, which are thrust up by the colder, and therefore more condens'd and heavie, is caus'd an undulation or wavering of the Object; for I think, that there are very few will grant, that Glass, by as gentle a heat as may be endur'd by ones hand, should send forth any of its parts in steams or vapours, which does not seem to be much wasted by that violent fire of the green Glass-house; but, if yet it be doubted, let Experiment be further made with that body that is accounted, by Chymists and others, the most ponderous and fix'd in the world; for by heating of a piece of Gold, and proceeding in the same manner, you may find the same effects.

This trembling and shaking of the Rays, is more sensibly caus'd by an actual flame, or quick fire, or any thing else heated glowing hot; as by a Candle, live Coal, red-hot Iron, or a piece of Silver, and the like: the same also appears very conspicuous, if you look at an Object betwixt

which

which and your eye, the riſing ſmoak of ſome Chimney is interpos'd; which brings into my mind what I had once the opportunity to obſerve, which was, the Sun riſing to my eye juſt over a Chimney that ſent forth a copious ſteam of ſmoak; and taking a ſhort *Teleſcope*, which I had then by me, I obſerv'd the body of the Sun, though it was but juſt peep'd above the Horizon, to have its underſide, not onely flatted, and preſs'd inward, as it uſually is when neer the Earth; but to appear more protuberant downwards then if it had ſuffered no refraction at all; and beſides all this, the whole body of the Sun appear'd to tremble or dance, and the edges or limb to be very ragged or indented, undulating or waving, much in the manner of a flag in the Wind.

This I have likewiſe often obſerv'd in a hot Sunſhiny Summer's day, that looking on an Object over a hot ſtone,or dry hot earth,I have found the Object to be undulated or ſhaken, much after the ſame manner. And if you look upon any remote Object through a *Teleſcope* (in a hot Summer's day eſpecially) you ſhall find it likewiſe to appear tremulous. And further, if there chance to blow any wind, or that the air between you and the Object be in a motion or current, whereby the parts of it, both rarify'd and condens'd, are ſwiftly remov'd towards the right or left, if then you obſerve the Horizontal ridge of a Hill far diſtant,through a very good *Teleſcope*, you ſhall find it to wave much like the Sea, and thoſe waves will appear to paſs the ſame way with the wind.

From which,and many other Experiments, 'tis cleer that the lower Region of the Air,eſpecially that part of it which lieth neereſt to the Earth, has, for the moſt part,its conſtituent parcels variouſly agitated, either by heat or winds, by the firſt of which, ſome of them are made more rare, and ſo ſuffer a leſs refraction; others are interwoven, either with aſcending or deſcending vapours; the former of which being more light, and ſo more rarify'd,have likewiſe a leſs refraction; the latter being more heavie, and conſequently more denſe,have a greater.

Now, becauſe that heat and cold are equally diffus'd every way; and that the further it is ſpread, the weaker it grows; hence it will follow, that the moſt part of the under Region of the Air will be made up of ſeveral kinds of *lentes*, ſome whereof will have the properties of *Convex*, others of *Concave glaſſes*; which, that I may the more intelligibly make out, we will ſuppoſe in the eighth *Figure* of the 37. *Scheme*, that A repreſents an aſcending vapour, which, by reaſon of its being ſomewhat *Heterogeneous* to the ambient Air,is thereby thruſt into a kind of Globular form, not any where terminated, but gradually finiſhed, that is, it is moſt rarify'd in the middle about A, ſomewhat more condens'd about B B, more then that about C C; yet further,about D D, almoſt of the ſame denſity with the ambient Air about E E; and laſtly, incloſed with the more denſe Air F F, ſo that from A, to F F, there is a continual increaſe of denſity. The reaſon of which will be manifeſt, if we conſider the riſing vapour to be much warmer then the ambient heavie Air; for by the coldneſs of the ambient Air, the ſhell E E will be more refrigerated then D D,and that then C C,which will be yet more then B B, and that

more

more then A; ſo that from F to A, there is a continual increaſe of heat, and conſequently of rarity; from whence it will neceſſarily follow, that the Rays of light will be inflected or refracted in it, in the ſame manner as they would be in a *Concave-glaſs*; for the Rays *GKI*, *G K I* will be inflected by *G K H*, *G K H*, which will eaſily follow from what I before explained concerning the inflection of the *Atmoſphere*.

On the other ſide, a deſcending vapour, or any part of the air included by an aſcending vapour, will exhibit the ſame effects with a *Convex lens*; for, if we ſuppoſe, in the former Figure, the quite contrary conſtitution to that laſt deſcrib'd; that is, the ambient Air F F being hotter then any part of that matter within any circle, therefore the coldeſt part muſt neceſſarily be A, as being fartheſt remov'd from the heat, all the intermediate ſpaces will be gradually diſcriminated by the continuall mixture of heat and cold, ſo that it will be hotter at E E, then D D, in D D then C C, in C C then B B, and in B B then A. From which, a like refraction and condenſation will follow; and conſequently a leſſer or greater refraction, ſo that every included part will refract more then the including, by which means the Rays, G K I, G K I, coming from a Starr, or ſome remote Object, are ſo inflected, that they will again concurr and meet, in the point M. By the interpoſition therefore of this deſcending vapour the viſible body of the Star, or other Object, is very much augmented, as by the former it was diminiſhed.

From the quick conſecutions of theſe two, one after another, between the Object and your eye, cauſed by their motion upwards or downwards, proceeding from their levity or gravity, or to the right or left, proceeding from the wind, a Starr may appear, now bigger, now leſs, then really it would otherwiſe without them; and this is that property of a Starr, which is commonly call'd twinkling, or ſcintillation.

The reaſon why a Star will now appear of one colour, now of another, which for the moſt part happens when 'tis neer the Horizon, may very eaſily be deduc'd from its appearing now in the middle of the vapour, other whiles neer the edge; for if you look againſt the body of a Starr with a *Teleſcope* that has a pretty deep *Convex* Eye-glaſs, and ſo order it, that the Star may appear ſometimes in one place, and ſometimes in another of it; you may perceive this or that particular colour to be predominant in the apparent Figure of the Starr, according as it is more or leſs remote from the middle of the *Lens*. This I had here further explain'd, but that it does more properly belong to another place.

I ſhall therefore onely add ſome few Quæries, which the conſideration of theſe particulars hinted, and ſo finiſh this Section.

And the firſt I ſhall propound is, Whether there may not be made an artificial tranſparent body of an exact Globular Figure that ſhall ſo inflect or refract all the Rays, that, coming from one point, fall upon any *Hemiſphere* of it; that every one of them may meet on the oppoſite ſide, and croſs one another exactly in a point; and that it may do the like alſo with all the Rays that, coming from a *lateral* point, fall upon any other *Hemiſphere*; for if ſo, there were to be hoped a perfection of *Dioptricks*,

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and a tranſmigration into heaven, even whil'ſt we remain here upon earth in the fleſh, and a deſcending or penetrating into the center and innermoſt receſſes of the earth, and all earthly bodies; nay, it would open not onely a cranney, but a large window (as I may ſo ſpeak) into the Shop of Nature, whereby we might be enabled to ſee both the tools and operators, and the very manner of the operation it ſelf of Nature; this, could it be effected, would as farr ſurpaſs all other kind of perſpectives as the vaſt extent of Heaven does the ſmall point of the Earth, which diſtance it would immediately remove, and unite them, as 'twere, into one, at leaſt, that there ſhould appear no more diſtance between them then the length of the Tube, into the ends of which theſe Glaſſes ſhould be nſerted: Now, whether this may not be effected with parcels of Glaſs of ſeveral denſities, I have ſometimes proceeded ſo farr as to doubt (though in truth, as to the general, I have wholly deſpair'd of it) for I have often obſerv'd in Optical Glaſſes a very great variety of the parts, which are commonly called Veins; nay, ſome of them round enough (for they are for the moſt part, drawn out into ſtrings) to conſtitute a kind of *lens*.

This I ſhould further proceed to hope, had any one been ſo inquiſitive as to have found out the way of making any tranſparent body, either more denſe or more rare; for then it might be poſſible to compoſe a Globule that ſhould be more denſe in the middle of it, then in any other part, and to compoſe the whole bulk, ſo as that there ſhould be a continual gradual tranſition from one degree of denſity to another; ſuch as ſhould be found requiſite for the deſired inflection of the *tranſmigrating* Rays; but of this enough at preſent, becauſe I may ſay more of it when I ſet down my own Trials concerning the melioration of *Dioptricks*, where I ſhall enumerate with how many ſeveral ſubſtances I have made both *Microſcopes*, and *Teleſcopes*, and by what and how many, ways: Let ſuch as have leiſure and opportunity farther conſider it.

The next Quæry ſhall be, whether by the ſame collection of a more denſe body then the other, or at leaſt, of the denſer part of the other, there might not be imagin'd a reaſon of the apparition of ſome new fix'd Stars, as thoſe in the Swan, *Caſſiope's Charr*, *Serpentarius*, *Piſcis*, *Cetus*, &c.

Thirdly, Whether it be poſſible to define the height of the *Atmoſphere* from this inflection of the Rays, or from the Quickſilver Experiment of the rarifaction or extenſion of the Air.

Fourthly, Whether the diſparity between the upper and under Air be not ſometimes ſo great, as to make a reflecting ſuperficies; I have had ſeveral Obſervations which ſeem to have proceeded from ſome ſuch cauſe, but it would be too long to relate and examine them. An Experiment, alſo ſomewhat analogous to this, I have made with Salt-water and Freſh, which two liquors, in moſt Poſitions, ſeem'd the ſame, and not to be ſeparated by any determinate ſuperficies, which ſeparating ſurface yet in ſome other Poſitions did plainly appear.

And if ſo, Whether the reaſon of the equal bounding or *terminus* of the under parts of the clouds may not proceed from this cauſe; whether, ſecondly,

ſecondly, the Reaſon of the apparition of many Suns may not be found out, by conſidering how the Rays of the Sun may ſo be reflected, as to deſcribe a pretty true Image of the body, as we find them from any regular Superficies. Whether alſo this may not be found to cauſe the apparition of ſome of thoſe *Parelii*, or counterfeit Suns, which appear coloured, by refracting the Rays ſo, as to make the body of the Sun appear in quite another place then really it is. But of this more elſewhere.

5. Whether the *Phænomena* of the Clouds may not be made out by this diverſity of denſity in the upper and under parts of the Air, by ſuppoſing the Air above them to be much lighter then they themſelves are, and they themſelves to be yet lighter then that which is ſubjacent to them, many of them ſeeming to be the ſame ſubſtance with the Cobwebs that fly in the Air after a Fog.

Now that ſuch a conſtitution of the Air and Clouds, if ſuch there be, may be ſufficient to perform this effect, may be confirm'd by this Experiment.

Make as ſtrong a Solution of Salt as you are able, then filling a Glaſs of ſome depth half full with it, fill the other half with freſh Water, and poyſe a little Glaſs-bubble, ſo as that it may ſink pretty quick in freſh Water, which take and put into the aforeſaid Glaſs, and you ſhall find it to ſink till it comes towards the middle, where it will remain fixt, without moving either upwards or downwards. And by a ſecond Experiment, of poiſing ſuch a bubble in water, whoſe upper part is warmer, and conſequently lighter, then the under, which is colder and heavier; the manner of which follows in this next Quæry, which is,

6. Whether the rarifaction and condenſation of Water be not made after the ſame manner, as thoſe effects are produc'd in the Air by heat; for I once pois'd a ſeal'd up Glaſs-bubble ſo exactly, that never ſo ſmall an addition would make it ſink, and as ſmall a detraction make it ſwim, which ſuffering to reſt in that Veſſel of Water for ſome time, I alwayes found it about noon to be at the bottom of the Water, and at night, and in the morning, at the top: Imagining this to proceed from the Rarifaction of the Water, caus'd by the heat, I made tryal, and found moſt true; for I was able at any time, either to depreſs, or raiſe it, by heat and cold; for if I let the Pipe ſtand for ſome time in cold water, I could eaſily raiſe the Bubble from the bottom, whither I had a little afore detruded it, by putting the ſame Pipe into warm Water. And this way I have been able, for a very conſiderable time, to keep a Bubble ſo poys'd in the Water, as that it ſhould remain in the middle, and neither ſink, nor ſwim: For gently heating the upper part of the Pipe with a Candle, Coal, or hot Iron, till I perceived the Bubble begin to deſcend, then forbearing, I have obſerved it to deſcend to ſuch or ſuch a ſtation, and there to remain ſuſpended for ſome hours, till the heat by degrees were quite vaniſhed, when it would again aſcend to its former place. This I have alſo often obſerved naturally performed by the heat of the Air, which being able to rarifie the upper parts of the Water ſooner then the lower, by reaſon of its immediate contact, the heat of the Air

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has ſometimes ſo ſlowly increaſed, that I have obſerved the Bubble to be ſome hours in paſſing between the top and bottom.

7. Whether the appearance of the *Pike* of *Tenerif*, and ſeveral other high Mountains, at ſo much greater a diſtance then ſeems to agree with their reſpective heights, be not to be attributed to the *Curvature* of the viſual Ray, that is made by its paſſing obliquely through ſo differingly *Denſe* a Medium from the top to the eye very far diſtant in the Horizon: For ſince we have already, I hope, made it very probable, that there is ſuch an *inflection* of the Rays by the differing denſity of the parts of the Air; and ſince I have found, by ſeveral Experiments made on places comparatively not very high, and have yet found the preſſure ſuſtain'd by thoſe parts of the Air at the top and bottom, and alſo their differing Expanſions very conſiderable: Inſomuch that I have found the preſſure of the *Atmoſphere* lighter at the top of St. *Paul's* Steeple in *London* (which is about two hundred foot high) then at the bottom by a ſixtieth or fiftieth part, and the expanſion at the top greater then that at the bottom by neer about ſo much alſo; for the *Mercurial Cylinder* at the bottom was about 39. inches, and at the top half an inch lower; the Air alſo included in the Weather-glaſs, that at the bottom fill'd only 155. ſpaces, at the top fill'd 158. though the heat at the top and bottom was found exactly the ſame with a ſcal'd *Thermometer*: I think it very rational to ſuppoſe, that the greateſt Curvature of the Rays is made neareſt the Earth, and that the inflection of the Rays, above 3. or 4. miles upwards, is very inconſiderable, and therefore that by this means ſuch calculations of the height of Mountains, as are made from the diſtance they are viſible in the Horizon, from the ſuppoſal that that Ray is a ſtraight Line (that from the top of the Mountain is, as'twere, a Tangent to the Horizon whence it is ſeen) which really is a *Curve*, is very erroneous. Whence, I ſuppoſe, proceeds the reaſon of the exceedingly differing Opinions and Aſſertions of ſeveral Authors, about the height of ſeveral very high Hills.

8. Whether this Inflection of the Air will not very much alter the ſuppoſed diſtances of the Planets, which ſeem to have a very great dependence upon the Hypothetical refraction or inflection of the Air, and that refraction upon the hypothetical height and denſity of the Air: For ſince (as I hope) I have here ſhewn the Air to be quite otherwiſe then has been hitherto ſuppos'd, by manifeſting it to be, both of a vaſt, at leaſt an uncertain, height, and of an unconſtant and irregular denſity; It muſt neceſſarily follow, that its inflection muſt be varied accordingly: And therefore we may hence learn, upon what ſure grounds all the Aſtronomers hitherto have built, who have calculated the diſtance of the Planets from their Horizontal *Parallax*; for ſince the Refraction and *Parallax* are ſo nearly ally'd, that the one cannot be known without the other, eſpecially by any wayes that have been yet attempted, how uncertain muſt the *Parallax* be, when the Refraction is unknown? And how eaſie is it for Aſtronomers to aſſign what diſtance they pleaſe to the Planets, and defend them, when they have ſuch a curious *ſubterfuge* as that of Refraction, wherein a very little variation will allow them liberty enough to place the Celeſtial Bodies at what diſtance they pleaſe.

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If therefore we would come to any certainty in this point, we must go other wayes to work; and as I have here examined the height and refractive property of the Air by other wayes then are usual, so must we find the Parallax of the Planets by wayes not yet practised; and to this end, I cannot imagine any better way, then the Observations of them by two persons at very far distant parts of the Earth, that lye as neer as may be under the same Meridian, or Degree of longitude, but differing as much in latitude, as there can be places conveniently found: These two persons, at certain appointed times, should (as near as could be) both at the same time, observe the way of the *Moon*, *Mars*, *Venus*, *Jupiter*, and *Saturn*, amongst the fixt Stars, with a good large *Telescope*, and making little Iconismes, or pictures, of the small fixed Stars, that appear to each of them to lye in or near the way of the Center of the Planet, and the exact measure of the apparent Diameter; from the comparing of such Observations together, we might certainly know the true distance, or Parallax, of the Planet. And having any one true Parallax of these Planets, we might very easily have the other by their apparent Diameters, which the *Telescope* likewise affords us very accurately. And thence their motions might be much better known, and their Theories more exactly regulated. And for this purpose I know not any one place more convenient for such an Observation to be made in, then in the Island of St. *Helena*, upon the Coast of *Africk*, which lyes about sixteen degrees to the Southwards of the Line, and is very near, according to the latest Geographical Maps, in the same Meridian with *London*; for though they may not perhaps lye exactly in the same, yet their Observations, being ordered according to what I shall anon shew, it will not be difficult to find the true distance of the Planet. But were they both under the same Meridian, it would be much better.

And because Observations may be much easier, and more accurately made with good *Telescopes*, then with any other Instruments, it will not, I suppose, seem impertinent to explain a little what wayes I judge most fit and convenient for that particular. Such therefore as shall be the Observators for this purpose, should be furnished with the best *Telescopes* that can be had, the longer the better and more exact will their Observations be, though they are somewhat the more difficultly manag'd. These should be fitted with a *Rete*, or divided Scale, plac'd at such a distance within the Eye-glass, that they may be distinctly seen, which should be the measures of minutes and seconds; by this Instrument each Observator should, at certain prefixt times, observe the Moon, or other Planet, in, or very near, the Meridian; and because it may be very difficult to find two convenient stations that will happen to be just under the same Meridian, they shall, each of them, observe the way of the Planet, both for an hour before, and an hour after, it arrive at the Meridian; and by a line, or stroke, amongst the small fixed Stars, they shall denote out the way that each of them observ'd the Center of the Planet to be mov'd in for those two hours: These Observations each of them shall repeat for many dayes together, that both it may happen, that both of

them may sometimes make their Observations together, and that from divers Experiments we may be the better assured of what certainty and exactness such kind of Observations are like to prove. And because many of the Stars which may happen to come within the compass of such an *Iconism*, or Map, may be such as are only visible through a good *Telescope*, whose Positions perhaps have not been noted, nor their longitudes, or latitudes, any where remarked; therefore each Observator should indeavour to insert some fixt Star, whose longitude, and latitude, is known; or with his *Telescope* he shall find the Position of some notable *telescopical* Star, inserted in his Map, to some known fixt Star, whose place in the *Zodiack* is well defin'd.

Having by this means found the true distance of the Moon, and having observed well the *apparent Diameter* of it at that time with a good *Telescope*, it is easie enough, by one single Observation of the apparent Diameter of the Moon with a good Glass, to determine her distances in any other part of her *Orbit*, or *Dragon*; and consequently, some few Observations will tell us, whether she be mov'd in an *Ellipsis*, (which, by the way, may also be found, even now, though I think we are yet ignorant of her true distance) and next (which without such Observations, I think, we shall not be sure of) we may know exactly the bigness of that *Ellipsis*, or Circle, and her true velocity in each part, and thereby be much the better inabled to find out the true cause of all her Motions. And though, even now also, we may, by such Observations in one station, as here at *London*, observe the *apparent Diameter* and motion of the Moon in her *Dragon*, and consequently be inabled to make a better ghess at the *Species* or kind of Curve, in which she is mov'd, that is, whether it be sphærical, or *elliptical*, or neither, and with what proportional velocities she is carried in that Curve; yet till her true *Parallax* be known, we cannot determine either.

Next, for the true distance of the Sun, the best way will be, by accurate Observations, made in both these forementioned stations, of some convenient Eclipse of the Sun, many of which may so happen, as to be seen by both; for the *Penumbra* of the Moon may, if she be sixty Semidiameters distant from the Earth, and the Sun above seven thousand, extend to about seventy degrees on the Earth, and consequently be seen by Observators as far distant as *London*, and St. *Helena*, which are not full sixty nine degrees distant. And this would much more accurately, then any way that has been yet used, determine the Parallax, and distance, of the Sun; for as for the Horizontal Parallax I have already shewn it sufficiently uncertain; nor is the way of finding it by the Eclipse of the Moon any other then hypothetical; and that by the difference of the true and apparent quadrature of the Moon is less not uncertain, witness their Deductions from it, who have made use of it; for *Vendeline* puts that difference to be but 4'. 30". whence he deduces a vast distance of the Sun, as I have before shewn. *Ricciolo* makes it full 30'. 00. but *Reinoldus*, and *Kircher*, no less then three degrees. And no wonder, for if we examine the *Theory*, we shall find it so complicated with uncertainties.

First,

First, From the irregular surface of the Moon, and from several Parallaxes, that unless the *Dichotomy* happen in the *Nonagesimus* of the *Eclip-tick*, and that in the Meridian, *&c.* all which happen so very seldom, that it is almost impossible to make them otherwise then uncertainly. Besides, we are not yet certain, but that there may be somewhat about the Moon *analogus* to the Air about the Earth, which may cause a refraction of the light of the Sun, and consequently make a great difference in the apparent *dichotomy* of the Moon. Their way indeed is very rational and ingenious; and such as is much to be preferr'd before the way by the Horizontal Parallax, could all the uncertainties be remov'd, and were the true distance of the Moon known.

But because we find by the Experiments of *Vendiline*, *Reinoldus*, &c. that Observations of this kind are very uncertain also: It were to be wisht, that such kind of Observations, made at two very distant stations, were promoted. And it is so much the more desirable, because, from what I have now shewn of the nature of the Air, it is evident, that the refraction may be very much greater then all the Astronomers hitherto have imagined it: And consequently, that the distance of the Moon, and other Planets, may be much lesse then what they have hitherto made it.

For first, this Inflection, I have here propounded, will allow the shadow of the Earth to be much shorter then it can be made by the other *Hypothesis* of refraction, and consequently, the Moon will not suffer an Eclipse, unless it comes very much nearer the Earth then the Astronomers hitherto have supposed it.

Secondly, There will not in this *Hypothesis* be any other shadow of the Earth, such as *Kepler* supposes, and calls the *Penumbra*, which is the shadow of the refracting *Atmosphere*; for the bending of the Rays being altogether caus'd by *Inflection*, as I have already shewn, all that part which is ascribed by *Kepler*, and others after him, to the *Penumbra*, or dark part, which is without the *umbra terræ*, does clear vanish; for in this *Hypothesis* there is no refracting surface of the Air, and consequently there can be no shadows, such as appear in the ninth Figure of the 37. *Scheme*, where let A B C D represent the Earth, and E F G H the *Atmosphere*, which according to *Keplers* supposition, is like a Sphære of Water terminated with an exact surface E F G H, let the lines M F, L B, I D, K H, represent the Rays of the Sun; 'tis manifest, that all the Rayes between L B, and I D, will be reflected by the surface of the Earth B A D, and consequently, the conical space B O D would be dark and obscure; but, say the followers of *Kepler*, the Rays between M F, and L B, and between I D, and K H, falling on the *Atmosphere*, are refracted, both at their ingress and egress out of the *Atmosphere*, nearer towards the Axis of the spærical shadow C O, and consequently, inlighten a great part of that former dark Cone, and shorten, and contract, its top to N. And because of this Reflection of these Rays, say they, there is superinduc'd another shell of a dark Cone F P H, whose Apex P is yet further distant from the Earth: By this *Penumbra*, say they, the Moon is

is Eclipsed, for it alwayes passes between the lines 1 2, and 3 4.

To which I say, That if the Air be such, as I have newly shewn it to be, and consequently cause such an inflection of the Rays that fall into it, those dark *Penumbra's* F Y Z Q, H X V T, and O R P S, will all vanish. For if we suppose the Air indefinitely extended, and to be no where bounded with a determinate refracting surface, as I have shewn it uncapable of having, from the nature of it; it will follow, that the Moon will no where be totally obscured, but when it is below the Apex N, of the dark blunt Cone of the Earth's shadow: Now, from the supposition, that the Sun is distant about seven thousand Diameters, the point N, according to calculation, being not above twenty five terrestrial Semidiameters from the Center of the Earth: It follows, that whensoever the Moon eclipsed is totally darkned, without affording any kind of light, it must be within twenty five Semidiameters of the Earth, and consequently much lower then any Astronomers have hitherto put it.

This will seem much more consonant to the rest of the secundary Planets; for the highest of *Jupiter's* Moons is betweeu twenty and thirty *Jovial Semidiameters* distant from the Center of *Jupiter*; and the Moons of *Saturn* much about the same number of *Saturnial Semidiameters* from the Center of that Planet.

But these are but conjectures also, and must be determin'd by such kind of Observations as I have newly mention'd.

Nor will it be difficult, by this *Hypothesis*, to salve all the appearances of Eclipses of the Moon, for in this *Hypothesis* also, there will be, on each side of the shadow of the Earth, a *Penumbra*, not caus'd by the Refraction of the Air, as in the *Hypothesis* of *Kepler*; but by the faint inlightning of it by the Sun: For if, in the sixth Figure, we suppose E S Q, and G S R, to be the Rays that terminate the shadow from either side of the Earth; E S Q coming from the upper limb of the Sun, and G S R from the under; it will follow, that the shadow of the Earth, within those Rays, that is, the Cone G S E, will be totally dark. But the Sun being not a point, but a large *area* of light, there will be a secondary dark Cone of shadow E P G, which will be caus'd by the earth's hindring part of the Rays of the Sun from falling on the parts G P R, and E P Q. of which halved shadow, or *Penumbra*, that part will appear brightest which lyes nearest the terminating Rayes G P, and E P, and those darker that lye nearest to G S, and E S: when therefore the Moon appears quite dark in the middle of the Eclipse, she must be below S, that is, between S and F; when she appears lighter near the middle of the Eclipse, she must pass some where between R Q and S; and when she is alike light through the whole Eclypse, she must pass between R Q, and P.

Observ.

Obferv. LIX. *Of multitudes of fmall* Stars *difcoverable by the* Telefcope.

HAving, in the laft Obfervation, premis'd fome particulars obfervable in the *medium*, through which we muft look upon *Cœleftial* Objects, I fhall here add one Obfervation of the Bodies themfelves; and for a *fpecimen* I have made choice of the *Pleiades*, or feven Stars, commonly fo called (though in our time and Climate there appear no more then fix to the naked eye) and this I did the rather, becaufe the defervedly famous *Galileo*, having publifht a Picture of this *Afterifme*, was able, it feems, with his Glafs to difcover no more then thirty fix, whereas with a pretty good twelve foot *Telefcope*, by which I drew this 38 *Iconifm*, I could very plainly difcover feventy eight, placed in the order they are ranged in the Figure, and of as many differing Magnitudes as the *Afterisks*, wherewith they are Marked, do fpecifie; there being no lefs then fourteen feveral Magnitudes of thofe Stars, which are compris'd within the draught, the biggeft whereof is not accounted greater then one of the third Magnitude; and indeed that account is much too big, if it be compared with other Stars of the third Magnitude, efpecially by the help of a *Telefcope*; for then by it may be perceiv'd, that its fplendor, to the naked eye, may be fomewhat augmented by the three little Stars immediately above it, which are near adjoyning to it. The *Telefcope* alfo difcovers a great variety, even in the bignefs of thofe, commonly reckon'd, of the firft, fecond, third, fourth, fifth, and fixth Magnitude; fo that fhould they be diftinguifh'd thereby, thofe fix Magnitudes would, at leaft, afford no lefs then thrice that number of Magnitudes, plainly enough diftinguifhable by their Magnitude, and brightnefs; fo that a good twelve foot Glafs would afford us no lefs then twenty five feveral Magnitudes. Nor are thefe all, but a longer Glafs does yet further, both more nicely diftinguifh the Magnitudes of thofe already noted, and alfo difcover feveral other of fmaller Magnitudes, not difcernable by the twelve foot Glafs: Thus have I been able, with a good thirty fix foot Glafs, to difcover many more Stars in the *Pleiades* then are here delineated, and thofe of three or four diftinct Magnitudes lefs then any of thofe fpots of the fourteenth Magnitude. And by the twinkling of divers other places of this *Afterifme*, when the Sky was very clear, I am apt to think, that with longer Glaffes, or fuch as would bear a bigger *aperture*, there might be difcovered multitudes of other fmall Stars, yet inconfpicuous. And indeed, for the difcovery of fmall Stars, the bigger the *aperture* be, the better adapted is the Glafs; for though perhaps it does make the feveral fpecks more radiant, and glaring, yet by that means, uniting more Rays very near to one point, it does make many of thofe radiant points confpi-

cuous, which, by putting on a leſs *aperture*, may be found to vaniſh; and therefore, both for the diſcovery of the fixt Star, and for finding the *Satellites* of *Jupiter*, before it be out of the day, or twilight, I alwayes leave the Object-glaſs as clear without any *aperture* as I can, and have thereby been able to diſcover the *Satellites* a long while before; I was able to diſcern them, when the ſmaller *apertures* were put on; and at other times, to ſee multitudes of other ſmaller Stars, which a ſmaller *aperture* makes to diſappear.

In that notable *Aſteriſm* alſo of the Sword of *Orion*, where the ingenious Monſieur *Hugens van Zulichem* has diſcovered only three little Stars in a cluſter, I have with a thirty ſix foot Glaſs, without any *aperture* (the breadth of the Glaſs being about ſome three inches and a half) diſcover'd five, and the twinkling of divers others up and down in divers parts of that ſmall milky Cloud.

So that 'tis not unlikely, but that the meliorating of *Teleſcopes* will afford as great a variety of new Diſcoveries in the Heavens, as better *Microſcopes* would among ſmall terreſtrial Bodies, and both would give us infinite cauſe, more and more to admire the omnipotence of the Creator.

Obſerv. LX. *Of the* Moon.

HAving a pretty large corner of the Plate for the ſeven Starrs, void, for the filling it up, I have added one ſmall *Specimen* of the appearance of the parts of the Moon, by deſcribing a ſmall ſpot of it, which, though taken notice of, both by the Excellent *Hevelius*, and called *Mons Olympus* (though I think ſomewhat improperly, being rather a vale) and repreſented by the Figure X, of the 38. *Scheme*, and alſo by the Learn'd *Ricciolus*, who calls it *Hipparchus*, and deſcribes it by the Figure Y, yet how far ſhort both of them come of the truth, may be ſomewhat perceiv'd by the draught, which I have here added of it, in the Figure Z, (which I drew by a thirty foot Glaſs, in *October* 1664. juſt before the Moon was half inlightned) but much better by the Reader's diligently obſerving it himſelf, at a convenient time, with a Glaſs of that length, and much better yet with one of threeſcore foot long; for through theſe it appears a very ſpacious Vale, incompaſſed with a ridge of Hills, not very high in compariſon of many other in the Moon, nor yet very ſteep. The Vale it ſelf A B C D, is much of the figure of a Pear, and from ſeveral appearances of it, ſeems to be ſome very fruitful place, that is, to have its ſurface all covered over with ſome kinds of vegetable ſubſtances; for in all poſitions of the light on it, it ſeems to give a much fainter reflection then the more barren tops of the incompaſſing Hills, and thoſe a much fainter then divers other cragged, chalky, or rocky Mountains of the Moon. So that I am not unapt to think, that the Vale may have

Vegetables

Vegetables *analogus* to our Graſs, Shrubs, and Trees; and moſt of theſe incompaſſing Hills may be covered with ſo thin a vegetable Coat, as we may obſerve the Hills with us to be, ſuch as the ſhort Sheep paſture which covers the Hills of *Salisbury* Plains.

Up and down in ſeveral parts of this place here deſcrib'd (as there are multitudes in other places all over the ſurface of the Moon) may be perceived ſeveral kinds of pits, which are ſhap'd almoſt like a diſh, ſome bigger, ſome leſs, ſome ſhallower, ſome deeper, that is, they ſeem to be a hollow *Hemiſphere*, incompaſſed with a round riſing bank, as if the ſubſtance in the middle had been digg'd up, and thrown on either ſide. Theſe ſeem to me to have been the effects of ſome motions within the body of the Moon, *analogus* to our Earthquakes, by the eruption of which, as it has thrown up a brim, or ridge, round about, higher then the Ambient ſurface of the Moon, ſo has it left a hole, or depreſſion, in the middle, proportionably lower; divers places reſembling ſome of theſe, I have obſerv'd here in *England*, on the tops of ſome Hills, which might have been caus'd by ſome Earthquake in the younger dayes of the world. But that which does moſt incline me to this belief, is, firſt, the generality and diverſity of the Magnitude of theſe pits all over the body of the Moon. Next, the two experimental wayes, by which I have made a repreſentation of them.

The firſt was with a very ſoft and well temper'd mixture of Tobacco-pipe clay and Water, into which, if I let fall any heavy body, as a Bullet, it would throw up the mixture round the place, which for a while would make a repreſentation, not unlike theſe of the Moon; but conſidering the ſtate and condition of the Moon, there ſeems not any probability to imagine, that it ſhould proceed from any cauſe *analogus* to this; for it would be difficult to imagine whence thoſe bodies ſhould come; and next, how the ſubſtance of the Moon ſhould be ſo ſoft; but if a Bubble be blown under the ſurface of it, and ſuffer'd to riſe, and break; or if a Bullet, or other body, ſunk in it, be pull'd out from it, theſe departing bodies leave an impreſſion on the ſurface of the mixture, exactly like theſe of the Moon, ſave that theſe alſo quickly ſubſide and vaniſh. But the ſecond, and moſt notable, repreſentation was, what I obſerv'd in a pot of boyling Alabaſter, for there that powder being by the eruption of vapours reduc'd to a kind of fluid conſiſtence, if, whil'ſt it boyls, it be gently remov'd beſides the fire, the Alabaſter preſently ceaſing to boyl, the whole ſurface, eſpecially that where ſome of the laſt Bubbles have riſen, will appear all over covered with ſmall pits, exactly ſhap'd like theſe of the Moon, and by holding a lighted Candle in a large dark Room, in divers poſitions to this ſurface, you may exactly repreſent all the *Phænomena* of theſe pits in the Moon, according as they are more or leſs inlightned by the Sun.

And that there may have been in the Moon ſome ſuch motion as this, which may have made theſe pits, will ſeem the more probable, if we ſuppoſe it like our Earth, for the Earthquakes here with us ſeem to proceed from ſome ſuch cauſe, as the boyling of the pot of Alabaſter,

baſter, there ſeeming to be generated in the Earth from ſome ſubterraneous fires, or heat, great quantities of vapours, that is, of expanded aerial ſubſtances, which not preſently finding a paſſage through the ambient parts of the Earth, do, as they are increaſed by the ſupplying and generating principles, and thereby (having not ſufficient room to expand themſelves) extreamly condens'd, at laſt overpower, with their *elaſtick* properties, the reſiſtence of the incompaſſing Earth, and lifting it up, or cleaving it, and ſo ſhattering of the parts of the Earth above it, do at length, where they find the parts of the Earth above them more looſe, make their way upwards, and carrying a great part of the Earth before them, not only raiſe a ſmall brim round about the place, out of which they break, but for the moſt part conſiderable high Hills and Mountains, and when they break from under the Sea, divers times, mountainous Iſlands; this ſeems confirm'd by the *Vulcans* in ſeveral places of the Earth, the mouths of which, for the moſt part, are incompaſſed with a Hill of a conſiderable height, and the tops of thoſe Hills, or Mountains, are uſually ſhap'd very much like theſe pits, or diſhes, of the Moon: Inſtances of this we have in the deſcriptions of *Ætna* in *Sicily*, of *Hecla* in *Iceland*, of *Tenerif* in the *Canaries*, of the ſeveral *Vulcans* in *New-Spain*, deſcrib'd by *Gage*, and more eſpecially in the eruption of late years in one of the *Canary* Iſlands. In all of which there is not only a conſiderable high Hill raiſed about the mouth of the *Vulcan*, but, like the ſpots of the Moon, the top of thoſe Hills are like a diſh, or baſon. And indeed, if one attentively conſider the nature of the thing, one may find ſufficient reaſon to judge, that it cannot be otherwiſe; for theſe eruptions, whether of fire, or ſmoak, alwayes rayſing great quantities of Earth before them, muſt neceſſarily, by the fall of thoſe parts on either ſide, raiſe very conſiderable heaps.

Now, both from the figures of them, and from ſeveral other circumſtances; theſe pits in the Moon ſeem to have been generated much after the ſame manner that the holes in Alabaſter, and the *Vulcans* of the Earth are made. For firſt, it is not improbable, but that the ſubſtance of the Moon may be very much like that of our Earth, that is, may conſiſt of an earthy, ſandy, or rocky ſubſtance, in ſeveral of its ſuperficial parts, which parts being agitated, undermin'd, or heav'd up, by eruptions of vapours, may naturally be thrown into the ſame kind of figured holes, as the ſmall duſt, or powder of Alabaſter. Next, it is not improbable, but that there may be generated, within the body of the Moon, divers ſuch kind of internal fires and heats, as may produce ſuch Exhalations; for ſince we can plainly enough diſcover with a *Teleſcope*, that there are multitudes of ſuch kind of eruptions in the body of the Sun it ſelf, which is accounted the moſt noble Ætherial body, certainly we need not be much ſcandaliz'd at ſuch kind of alterations, or corruptions, in the body of this lower and leſs conſiderable part of the univerſe, the Moon, which is only ſecundary, or attendant, on the bigger, and more conſiderable body of the Earth. Thirdly, 'tis not unlikely, but that ſuppoſing ſuch a ſandy or mouldring ſubſtance to be

Now
the wh



Fig: X.

Fig: Y

Stellarum magnitudines

1 2 3 4 5 6 7 8 9 10 11 12 13 14

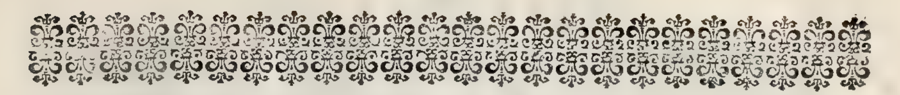
be there found, and ſuppoſing alſo a poſſibility of the generation of the internal *elaſtical* body (whether you will call it air or vapours) 'tis not unlikely, I ſay, but that there is in the Moon a principle of gravitation, ſuch as in the Earth. And to make this probable, I think, we need no better Argument, then the roundneſs, or globular Figure of the body of the Moon it ſelf, which we may perceive very plainly by the *Teleſcope*, to be (bating the ſmall inequality of the Hills and Vales in it, which are all of them likewiſe ſhap'd, or levelled, as it were, to anſwer to the center of the Moons body) perfectly of a Sphærical figure, that is, all the parts of it are ſo rang'd (bating the comparitively ſmall ruggedneſs of the Hills and Dales) that the outmoſt bounds of them are equally diſtant from the Center of the Moon, and conſequently, it is exceedingly probable alſo, that they are equidiſtant from the Center of gravitation; and indeed, the figure of the ſuperficial parts of the Moon are ſo exactly ſhap'd, according as they ſhould be, ſuppoſing it had a gravitating principle as the Earth has, that even the figure of thoſe parts themſelves is of ſufficient efficacy to make the gravitation, and the other two ſuppoſitions probable: ſo that the other ſuppoſitions may be rather prov'd by this conſiderable Circumſtance, or Obſervation, then this ſuppos'd Explication can by them; for he that ſhall attentively obſerve with an excellent *Teleſcope*, how all the Circumſtances, notable in the ſhape of the ſuperficial parts, are, as it were, exactly adapted to ſuit with ſuch a principle, will, if he well conſiders the uſual method of Nature in its other proceedings, find abundant argument to believe it to have really there alſo ſuch a principle; for I could never obſerve, among all the mountainous or prominent parts of the Moon (whereof there is a huge variety) that any one part of it was plac'd in ſuch a manner, that if there ſhould be a gravitating, or attracting principle in the body of the Moon, it would make that part to fall, or be mov'd out of its viſible poſture. Next, the ſhape and poſition of the parts is ſuch, that they all ſeem put into thoſe very ſhapes they are in by a gravitating power: For firſt, there are but very few clifts, or very ſteep declivities in the aſcent of theſe Mountains; for beſides thoſe Mountains, which are by *Hevelius* call'd the *Apennine* Mountains, and ſome other, which ſeem to border on the Seas of the Moon, and thoſe only upon one ſide, as is common alſo in thoſe Hills that are here on the Earth; there are very few that ſeem to have very ſteep aſcents, but, for the moſt part, they are made very round, and much reſemble the make of the Hills and Mountains alſo of the Earth; this may be partly perceived by the Hills incompaſſing this Vale, which I have here deſcrib'd; and as on the Earth alſo, the middlemoſt of theſe Hills ſeems the higheſt, ſo is it obvious alſo, through a good *Teleſcope*, in thoſe of the Moon; the Vales alſo in many are much ſhap'd like thoſe of the Earth, and I am apt to think, that could we look upon the Earth from the Moon, with a good *Teleſcope*, we might eaſily enough perceive its ſurface to be very much like that of the Moon.

Now whereas in this ſmall draught, (as there would be multitudes if the whole Moon were drawn after this manner) there are ſeveral little Ebullitions,

Ebullitions, or Dishes, even in the Vales themselves, and in the incompassing Hills also; this will, from this supposition, (which I have, I think, upon very good reason taken) be exceeding easily explicable; for, as I have several times also observ'd, in the surface of Alabaster so ordered, as I before describ'd, so may the later eruptions of vapours be even in the middle, or on the edges of the former; and other succeeding these also in time may be in the middle or edges of these, *&c.* of which there are Instances enough in divers parts of the body of the Moon, and by a boyling pot of Alabaster will be sufficiently exemplifi'd.

To conclude therefore, it being very probable, that the Moon has a principle of gravitation, it affords an excellent distinguishing Instance in the search after the cause of gravitation, or attraction, to hint, that it does not depend upon the diurnal or turbinated motion of the Earth, as some have somewhat inconsiderately supposed and affirmed it to do; for if the Moon has an attractive principle, whereby it is not only shap'd round, but does firmly contain and hold all its parts united, though many of them seem as loose as the sand on the Earth, and that the Moon is not mov'd about its Center; then certainly the turbination cannot be the cause of the attraction of the Earth; and therefore some other principle must be thought of, that will agree with all the secundary as well as primary Planets. But this, I confess, is but a probability, and not a demonstration, which (from any Observation yet made) it seems hardly capable of, though how successful future indeavours (promoted by the meliorating of Glasses, and observing particular circumstances) may be in this, or any other, kind, must be with patience expected.

FINIS.



THE TABLE.

explication

The Table.

Obſerv.

The Table.

The TABLE.

of

ERRATA.



ERRATA.

IN the Preface, Page 7. line 18. read *feet* : line 24. read *Gilbert, Harvy*.
Page 13. line ult. read *taste* : p. 34. l. 18. r. *small lens* : l. penult. r. *that proceeds from* : p. 40 l 44. r. *when you*: p. 48. l. 34. r. *broadest*: p. 57. l. 39. dele *be*: p. 62. l. 36. r. *water-drop* : p. 64. l. 9. r. *duction of G A C H* : l. 35. r. *impressions* : p. 96. l. 33. r *compose* : p. 100. l. 11. r. *Mersennus* : p. 106 l. 8. r. *extreamly* : p. 110 l 8. r. *as* : l. 12. r. *those* : p. 112. l. 32. r. *Aldrovandus, Wormius* : p. 121. l. 9. dele *of* : p. 128. l. 43, dele *from*: p. 129. l. 18. r *fifth place* : p. 130. l. 29. r. *Aerial menstruum* : p. 136. l. 39. r. *knew how* : p. 144. l. 2. r. *parts of the* : p. 147, l 36. r. *look'd on* : p. 161. l. 13. r. *body* : p 162 l. 17. dele *only* : p. 166. l. 11. r. 22 : l. 12. dele the Semicolon : l. 17. r, *place* : p. 167. l. 40. r. 22 : p. 172. l. 18. r. *and first for the* : p. 198. l. 17. r. *and an artific.* p. 215. l. ult r. *and from the* : p. 221. l. 4. r. *whence the under* : p. 234. l. 18. r. *to hope* : p. 238. l. 42. r. *is not less* : p. 240. l. 19. r. *Moon*.



